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CoCoNaut Polarimetric SAR Signature Trial

Small Vessels of Opportunity Collections off Tofino, BC

R.A. English, C. Liu, D. Schlingmeier and P.W. Vachon

Defence R&D Canada – Ottawa

TECHNICAL MEMORANDUM
DRDC Ottawa TM 2006-184
October 2006

Canada

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Abstract

This memorandum addresses DRDC Ottawa design, experimentation, and data collection components in the CoCoNaut airborne Synthetic Aperture Radar (SAR) trial conducted off Vancouver Island, BC, 15 September – 4 October, 2004, in conjunction with a Canadian Space Agency (CSA) deployment. Several controlled ships (commercial, military and Coast Guard) and land-based vehicles were instrumented as targets for polarimetric SAR (PolSAR) and Moving Target Indication (MTI) data acquisitions.

C-band SAR imagery was collected using the sensor on Environment Canada's CV-580 platform, with a radar calibration site was established at the Tofino Airport (CYAZ). Ground-truthing for targets of opportunity was highly desired and supporting efforts made to identify them through contact tracking and photography, employing CP-140 maritime patrol aircraft, aerial creel survey flights, Marine Communications and Traffic Service, contracted aerial photography flights, and the Recognized Maritime Picture (RMP).

Twenty lines of PolSAR data were collected, each covering a wide swath containing maritime targets of opportunity and all include the calibration site at CYAZ. Eight also contain a controlled CCG vessel exhibiting various speeds, incidence angles and aspect angles. Thirty-two lines of MTI data were collected. Sixteen contain controlled maritime targets, seven contain controlled land-based vehicles, four (one maritime, three land) contain only targets of opportunity, and five are calibration lines. Three further flights of PolSAR imagery were collected by CSA, each including a calibration pass over CYAZ. A representative analysis of a maritime target in PolSAR imagery is provided.

Résumé

Ce mémorandum décrit les composantes de dessin, d'expérimentation et de collection de données des essais de vol à Radar à Ouverture Synthétique (ROS) CoCoNaut, effectués par RDDC Ottawa et l'Agence Canadienne Spatiale (ASC), dans les environs de l'île de Vancouver, du 15 Septembre au 4 Octobre, 2004. Plusieurs navires contrôlés (commerciaux, militaires et Garde Côtière) et véhicules terrestres on été instrumentés afin de participer comme cibles pour l'acquisition de données ROS polarimétriques et d'élimination de cibles fixes.

Les images radar ont été acquises en utilisant le capteur ROS (bande-C) monté sur l'appareil CV-580 d'Environnement Canada. De plus, un site de calibration radar a été établi à l'aéroport de Tofino (CYAZ). La vérification au sol de cibles inopinés étant essentielle aux objectifs de l'essai, divers moyens d'identification et de photographie de ces cibles on été employés : l'appareil de patrouille maritime CP-140, plusieurs vols de photographie aérienne nolisés, le Service de Communication et de Trafic Maritimes ainsi que la Situation Maritime Générale (SMG).

Vingt axes de vol de données polarimétriques ont été captés, chaque axe couvrant un large couloir contenant plusieurs cibles maritimes inopinées. Chacun de ces axes de vol incluent le site de calibration à CYAZ. Huit de ces axes contiennent également un navire coopératif de la Garde Côtiàre du Canada (GCC) présentant une gamme de vitesses, d'angles d'incidence et d'angles d'aspect. Trente-deux axes de vol de données d'élimination d'échos fixes on aussi été captés. Seize d'entre-eux contiennent des cibles maritimes contrôlées, sept contiennent des cibles terrestres contrôlées, quatre (un axe maritime et trois terrestres) contiennent uniquement des cibles inopinées et cinq sont des axes de calibration seulement, survolant le site CYAZ. Trois vols polarimétriques supplémentaires ont été effectués par l'ASC, chacun contenant un axe de calibration au dessus de CYAZ. Une analyse représentative de cibles maritimes retrouvées dans les données polarimétriques, est aussi fournie.

Executive summary

Capabilities to exploit data from the upcoming RADARSAT-2 synthetic aperture radar (SAR) sensor are being developed by DRDC Ottawa in support of the Canadian Forces, including the Director Space Development's Polar Epsilon project. Algorithms to automate the characterization of ships at sea using RADARSAT-2's polarimetric and moving target indicator (MTI) modes can be largely validated prior to the launch of the satellite by acquiring data using the C-band SAR flown on Environment Canada's CV-580.

Previous studies on polarimetric signatures have focused on a single vessel, DRDC's CFAV *Quest*, and then on multiple vessels operating in tandem. The former work aims to implement and evaluate signature extraction algorithms on real-world data of a vessel for which extensive radio frequency (RF) modeling exists. The latter allows the resulting signature data to be validated as differences among vessels, rather than imaging geometry or environmental conditions. The CoCoNaut experiments extend the analysis capability by including non-controlled vessels, particularly small craft, that offer a wider selection of signatures, profiles and activity and allow the algorithms developed to be validated and demonstrated on a real scenario, including the contribution of information not otherwise available in the Recognized Maritime Picture (RMP).

DRDC has leveraged off a Canadian Space Agency (CSA) deployment of the CV-580 to the West Coast and obtained maritime polarimetric SAR (PolSAR) and MTI data off the coast of Vancouver Island in a region where significant supporting assets are available to record ground truth of targets of opportunity. In addition to contracted aerial photography support, access to a Canadian Forces CP-140 Maritime Patrol Aircraft, Department of Fisheries and Oceans' aerial Creel Survey flight, the Canadian Coast Guard's Marine Communications and Traffic Service, and the Recognized Maritime Picture (RMP) provide the ability to identify a significant number of non-controlled vessels appearing in the data collected.

During the 15 September – 4 October, 2004 CoCoNaut trial, held off Vancouver Island near Tofino on the west coast and Nanoose Bay on the east coast, twenty lines of PolSAR data were collected, each covering a wide swath containing maritime targets of opportunity, a controlled CCG vessel when present, and a calibration site at the Tofino Airport (CYAZ) on all west coast imagery. In addition, 32 lines of MTI data were collected: 16 of controlled vessels, 5 calibration lines, 10 of ground moving targets, and one containing only maritime targets of opportunity.

The resulting data set provides a unique, valuable asset toward enabling new maritime intelligence, surveillance and reconnaissance (ISR) capabilities, having identified 47 targets of opportunity that should appear in at least 1 and up to 15 acquired images, 23 of them identify the vessel by name and have corresponding photographs. In particular, the mix of controlled vessels and targets of opportunity operating in proximity and within the same images will provide a test bed for validating the robustness of algorithms to discriminate a specific target vessel from a broad set of false alarm contacts. The collection of coincident SAR imagery of the vessels with the high degree of ground-truth support data will allow any limitations or intra-vessel parameter dependencies to be more fully investigated.

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Sommaire

Les capacités d'exploitation de données provenant du capteur Radar à Ouverture Synthétique (ROS) sur RADARSAT-2 sont présentement en développement à RDDC Ottawa en support des Forces Canadiennes, y compris le projet Polar Epsilon. Les algorithmes pour automatiser l'interprétation de données maritimes provenant des modes polarimétriques et d'élimination de cibles fixes de RADARSAT-2 peuvent être éprouvés avant le lancement du satellite en obtenant des données ROS avec le capteur bande-C à bord de l'appareil CV-580 d'Environnement Canada.

Les études précédentes de signatures polarimétriques effectuées par RDDC sont fixées pour la plupart sur un seul navire, le CFAV *Quest*, et ensuite sur des formations de multiples navires. Les études du *Quest* ont pour bût de mettre en œuvre et d'évaluer les algorithmes d'extraction de signatures avec des données en provenance d'un navire dont l'interaction avec les fréquences radio est déjà modélisé en détail. Les études de formations permettent de valider les signatures résultantes comme différences entre vaisseaux, plutôt que de différences de géométrie d'illumination ou de conditions météorologiques. Les essais CoCoNaut visent à étendre cette capacité d'analyse en incluant comme cibles des navires plus petits et non-contrôlés. Ceux-ci présentent une gamme de profils, d'activités et de signatures polarimétriques et permettent de démontrer et de valider les algorithmes dans un scénario réel, avec l'inclusion d'information non disponible autrement dans la Situation Maritime Générale (SMG).

RDDC a profité d'un déploiement par l'Agence Canadienne Spatiale (ASC) de l'appareil CV-580 pour obtenir des données ROS maritimes polarimétriques et d'élimination d'échos fixes au large de l'Ile de Vancouver dans une région ou existent plusieurs actifs pouvant supporter la vérification au sol de cibles inopinées. En plus de vols nolisés pour photographier les cibles inopinées, l'utilisation d'un un avion de patrouille maritime CP-140 Aurora, de vols de patrouille du Ministère de Pêches et Océans, du Service de Communication et de Trafic Maritime de la Garde Côtière ainsi que de la SMG ont permis d'identifier un bon nombre de navires non-contrôlés apparaissant dans les données.

Les essais de vol CoCoNaut ont eu lieu dans l'Ile de Vancouver du 15 Septembre au 4 Octobre, 2004, près de Tofino sur la côte ouest et autour de Comox et Nanoose Bay sur la côte est. Vingt axes de vol de données polarimétriques ont été captés, chacun couvrant un large couloir contenant plusieurs cibles maritimes inopinées ainsi qu'un navire contrôlé de la Garde Côtière. Chaque axe de vol sur la côte ouest a aussi survolé le site de calibration à l'aéroport de Tofino (CYAZ). De plus, trente-deux axes de vol de données d'élimination d'échos fixes on été collectionnés comme suit : 16 axes de navires contrôlés, 10 axes de cibles terrestres en mouvement, 5 axes de calibration et un seul axe contenant uniquement des cibles inopinées.

L'ensemble résultant de données fournit un outil unique et très utile envers la mise en service de nouvelles capacités de Renseignement, Surveillance et Reconnaissance (RSR). Quarante-sept cibles inopinées qui devraient apparaître dans au moins une, et dans jusqu'à quinze images radar, ont été identifiées. Vingt-trois de ces cibles ont été identifiées

par nom et ont été photographiées par les ressources de vérification au sol. En particulier, le mélange de vaisseaux contrôlés et de cibles inopinées dans les mêmes images fournit un bon banc d'essai pour évaluer la robustesse des algorithmes qui visent à séparer la signature d'un navire particulier d'une gamme d'alarmes fausses. La collection simultanée d'images ROS de vaisseaux et de données de vérification au sol permet d'explorer en détail les dépendances paramétriques ainsi que les limites des algorithmes d'extraction de signatures polarimétriques.

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The Canadian Coast Guard — Pacific, under Patty Murphy provided access to Coast Guard Cutters, the *Cape St. James* and *Cape Cockburn*, and allowed instrumentation of the vessels. Thanks to the crews of the *Cape St. James* and *Cape Cockburn* for their participation in the trial as controlled targets, following maneuver scripts as provided.

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1 Introduction

The Collaborative Coastal and Nautical (CoCoNaut) trial was held along the west coast of Canada during the period September 15 – October 4, 2004. The main asset was the C/X-band polarimetric Synthetic Aperture Radar (SAR) deployed onboard the Environment Canada (EC) Convair 580 (CV-580) aircraft. The trial leveraged off a commitment by the Canadian Space Agency (CSA) to deploy the platform across western Canada to collect imagery as part of their Earth Observation Application Development Program (EOADP), using the airborne polarimetric SAR (PolSAR) at C-band to act as a testbed for the upcoming RADARSAT-2 satellite sensor.

The western deployment included having the CV-580 platform positioned along the southern coast of British Columbia, where Defence Research and Development Canada (DRDC) was able to task flight time to collect imagery in support of current projects at DRDC Ottawa. The initial proposals for SAR Experiments by DRDC Ottawa are given in Annex A. In addition to deploying the necessary support for the DRDC collections, support was extended as a contribution to the CSA effort in the form of a calibration site (Cal Site) and the logistics of transporting shared equipment.

The experiments proposed for the Radar Data Exploitation (RDE) group extend ongoing analysis on the polarimetric signature of maritime targets. The initial investigation, the Quest-2003 trial [2] October 1 – 9, 2003 located 240 nm south of Halifax, Nova Scotia, focused on collecting polarimetric SAR imagery of a single well-know target vessel, the CFAV *Quest*, for which significant RF modeling has been performed [3]. This data forms the basis for analysis and algorithm development for characterizing the polarimetric signature. A second trial, MarCoPola [4] held March 20 – 26, 2004 located 20 nm SSW of Halifax, Nova Scotia, expanded the data collection to include additional well-instrumented Canadian Coast Guard (CCG) vessels maneuvering in formation, as well as the *Quest*. This collection provides validation data to ensure that the polarimetric signatures are characteristic of differences between vessels and not the environmental states nor are specific to the activity or profile a vessel is presenting. The CoCoNaut experiments would extend the analysis capability by including non-controlled vessels, particularly small craft, that offer a wider selection of signatures, profiles and activity and allow the algorithms developed to be validated and demonstrated on a real scenario, including the contribution of information not otherwise available in the Recognized Maritime Picture (RMP).

Ground truth for maritime data is typically more difficult to collect than for land-based targets. The ability to collect ancillary information about target vessels being imaged by radar sensors is a valuable tool for research and development (R&D) into radar data exploitation techniques. Two significant sources of ground-truth at sea are available in southern BC. The first is the CCG Tofino Marine Communications and Traffic Service (MCTS) at Ucluelet, which is responsible for tracking all maritime traffic along the approaches to the Straits of Juan de Fuca. The second is the CP-140 Maritime Patrol Aircraft (MPA) from 19 Wing of the 407 Squadron based out of Canadian Forces Base (CFB) Comox, whose operations include tracking, investigating and photographing both ships and non-vessel detections over

a wide area of ocean.

With this foundation as a basis, further resources and opportunities could be employed to maximize the value of the data collection.

2 Trial Planning

The first level of planning imagery acquisition using the C/X-band polarimetric SAR is to coordinate locations for three critical components of the trial:

a. The airfield from which the CV-580 platform will operate. The aircraft requires several minutes to climb to altitude, during which approximately a 20 nm ground track will be covered, but cannot be imaged. The ability to descend rapidly does allow imaging to occur much closer to the landing field. A usable flight length of five hours [2] forces trade-offs between transit time requirements and imaging time on-station.
b. The location of the targets. To improve time on-station, targets should be located relatively close to the operations airfield. However, details of the targets, their environment, and their operation may limit the number of suitable locations available.
c. The location of the calibration site. To improve the utility of imagery collected, calibration targets, corner reflectors (CR) and active radar calibrators (ARC) with well known properties are typically deployed [5]. Measurements made on these calibration targets allow significant parameters characterizing the imagery to be calculated, and normalization to occur. Thus, some degree of acquisition-related parameters are eliminated from influencing target signatures. For optimal use, the CRs and ARCs need to be deployed well-spaced in an open environment with good line-of-sight (LOS) to the horizon with a low Radar Cross Section (RCS) background. Additionally, a ground-based Ashtech Global Positioning System (GPS) receiver is used to establish differential GPS (dGPS) during the CV-580 flight to enable accurate motion compensation, which improves the image quality. For multi-day missions, it is preferable to deploy this equipment at a relatively secure site, rather than one accessible to the public.

2.1 Trial Plan Fundamentals

With the importance being placed on ancillary information from the Tofino MCTS, the target location would preferably be set within the coverage area of the Mt. Ozzard radar installation. The radar has a normal operational range of 60 nm [6]. This region covers a large area of ocean (Figure 1). Around the time of the planned CV-580 deployment, expectations were for fishing vessels, pleasure craft, and ships transiting the Strait of Juan de Fuca to be operating in the coverage zone. For military vessels, operations could be available on the east coast of Vancouver Island in the Strait of Georgia, but not in the MCTS zone. CCG vessels could be also be available from various stations around the island.

Vancouver Island is a rugged, forested region, leaving few choices for establishing a good calibration site with clear LOS. Taking into account the central role of Mt. Ozzard, suitable sites in proximity to the radar installation is mostly limited to the flat open beaches or the

Figure 1: *CCG Tofino MCTS coverage zone with proposed imaging lines. Yellow arc shows 60 nm radius from Mt. Ozzard. Red curve depicts Canada - US territorial waters. Blue rectangles indicate proposed line imaging extents.*

cleared region within the Tofino Airport (CYAZ) compound. Due to the more secure nature of the airport compound, and the potential difficulties of operating in a sand environment, the preferable location for the calibration site was at CYAZ.

Taking advantage of having the calibration site located at the centre of the MCTS coverage zone, proposed imaging lines were established radiating from CYAZ at bearings of 180° T, 225° T, and 270° T. In principal, due to the coastline extending along a 133°/313° T bearing, much of the MCTS zone could be imaged with these three proposed lines (Figure 1).

With the calibration site and target locations proposed, the airfield for CV-580 operations could be selected. The top airfield candidates were CYAZ, Nanaimo Airport (CYCD), Comox Airport (CYQQ), and Vancouver Airport (CYVR). Considerations of traffic, distance, crew accommodation and support facilities yielded CYQQ as the preferred operations airfield. Additionally, the presence of CFB Comox attached to CYQQ allowed for shipping and logistics to be handled internally to the Department of National Defence (DND), as well as improved coordination with CP-140 support.

2.2 Target Planning

With a proposed set of image collections, more detailed target planning can occur. The initial set of targets — fishing vessels, pleasure craft, and shipping lane transits — are normally targets of opportunity. The inclusion of the MCTS data improves the utility of these targets by providing identifying information in the form of vessel tracks. To further increase the utility of these targets, high-quality photography of each target is desirable. CP-140 support is able to be tasked for this purpose on a limited basis, but always comes with the caveat that operational requirements will take precedence. As such, it is prudent to have another source of aerial photography.

The Department of Fisheries and Oceans (DFO) also has an interest in tracking fishing vessels, and typically contracts overflights of fishing fleets during the active seasons. These flights potentially offer a convenient platform to collect photography of targets being imaged by the SAR sensor. During the time period of CoCoNaut, DFO activity was sporadic, but did have a *Creel Survey* planned for Sept 25, as per Annex B. Additionally, the path of the flight was designed to overfly the areas known for the most activity. By comparing the Creel Survey coverage with the proposed image lines, it was determined that few targets should be expected for the 270° T image line, and so a preference for the other two proposed lines was established.

Contained within the footprint of the proposed image lines are several non-vessel targets of interest. In particular, two permanent buoys, one an EC Oceanographic Data Acquisition System (ODAS) weather buoy [7] at LaPerouse Bank, the other a TriAxys directional wave buoy located off Amphitrite Point. Both buoys are moored at fixed locations, see Table 1, which are shown in Figure 2. Since most maritime targets are mobile, the positions of these buoys provide reference points that are otherwise absent in most maritime trials. Also within the footprint of the proposed image lines is a well-know crash site of a World War

***Table 1:** Locations of proposed ancillary targets [8, 9]. These targets are static, although the buoys may shift from their average location due to wind and wave influences. Note that these influences are measured by the buoys as part of their normal operations.*

Target	Latitude	Longitude	UTM
Ucluelet TriAxys	48° 55' 31.4" N	125° 34' 00.5" W	10U 0311986 5422337
ODAS 46206	48° 49' 58.8" N	126° 00' 00.0" W	10U 0279853 5413232
Canso 11007	49° 04' 40" N	125° 49' 11" W	10U 0294091 5439932
Cessna 206	49° 29.7' N	126° 28.3' W	10U 0248623 5488279
Seneca	49° 26.9' N	126° 30.0' W	10U 0246331 5483187

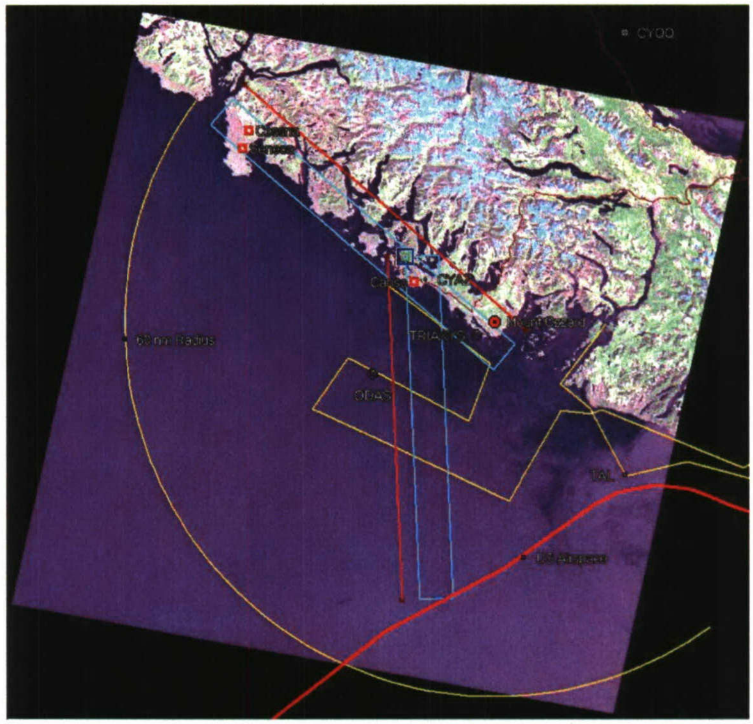
II Canso aircraft. Additional known aircraft crash sites, a Cessna and a Seneca, lay north along the coast at Estevan Point.

To best utilize these targets, it was determined that the proposed 225° T image line should be adjusted to centre along the track passing through both CYAZ and the ODAS buoy, and that an image line approximately parallel to the coast be added, one passing over the TriAxys buoy at one end and the crash sites at Estevan Point at the other. Thus, a trial plan to collect polarimetric SAR imagery consisting of two flights was derived:

a. Repeated imaging of the cardinal 180° T line, in both inbound and outbound directions, with the calibration site at CYAZ falling along the centre target line (i.e., with an incidence angle of 57°) in all cases. The extent of each image would be from CYAZ to the Canada-US territorial boundary. The final line before returning to CYQQ would be a coastal line with a heading of 313° T, with the TriAxys buoy and the midpoint of the Cessna and Seneca crash sites falling along the centre target line. Either an inshore or offshore look direction would be acceptable. The extent of the last line would be such to encompass all three ancillary targets. Figure 2(a) shows the plan with a coastal line looking offshore. The flight plan 04D1 (Annex C.2) for the EC CV-580 was generated to acquire this imagery.
b. Repeated imaging of the CYAZ-ODAS line, in both inbound and outbound directions, with both the calibration site at CYAZ and the ODAS buoy falling along the centre target line (i.e., a bearing of 211.5° T from CYAZ). The extent of each image would be from CYAZ to the 60 nm operational arc of the Mt. Ozzard radar. The final line before returning to CYQQ would be a coastal line, as per all collection requirements of the flight 1 coastal line, except with the opposite look direction. Figure 2(b) shows the plan with a coastal line looking inshore. The flight plan 04D2 (Annex C.3) for the EC CV-580 was generated to acquire this imagery.

To ensure that the collected imagery contains at least one target vessel, it is desirable to co-opt or contract the participation of one or more ships to participate in the trial and to be at near-optimal positions during imaging events. Access to CCG vessels in support of trials, like that of the CP-140, can be quite beneficial, but comes with the caveat of operational priorities taking precedence. Nevertheless, two CCG stations are located within operational distance of the trial region: Tofino Lifeboat station with the CCGC *Cape St. James* and

(a)



(b)

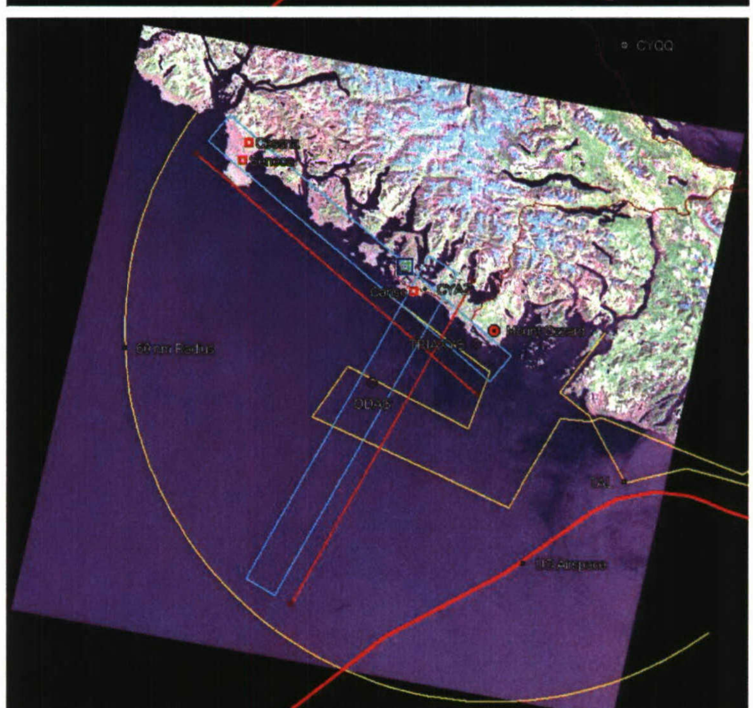


Figure 2: *Image lines planned for RDE collections: (a) flight 1, and (b) flight 2.*

Bamfield Lifeboat Station with the CCGC *Cape Calvert*. Ideally, both vessels could be utilized, but CCG operational requirements are to maintain a wide Search and Rescue coverage by keeping the vessels spread apart. Thus, the cooperation of the *Cape St. James* was pursued as the Tofino station requires less transit time. Instrumentation of the vessel with GPS and accelerometers add to the ancillary data of this target vessel. Having the *Cape St. James* maneuver to course and speed specifications for each image line also controls important variables.

Target detection in imagery can either be accomplished by locating the target itself, or by finding evidence of the target's interaction with the environment. In the maritime situation, this is often accomplished via wakes or other disturbances to ocean surface features. Much of this experiment's requirements can be achieved using the polarimetric SAR collections indicated above. To acquire imagery of specific military targets, either surface or subsurface, imaging geometries with centre lines on the target will be required. Since knowledge of Canadian Forces (CF) operations is not generally available in advance, contingencies to replace lines from either flight a or b with CF target lines should be expected.

In addition to the polarimetric SAR mode, Moving Target Indicator (MTI) data can be collected by the radar sensor onboard the CV-580, but both modes cannot be operated simultaneously. To acquire MTI data, additional flights must be planned. Employing the *Cape St. James* as indicated above, a well understood Maritime MTI (MMTI) target has been created and is ideal for the centre target of an MTI collection flight by the CV-580 Convair. Since the ODAS 46206 buoy continuously collects wind and wave data, operating the *Cape St. James* in proximity to the buoy allows this ancillary data to augment the knowledge about environmental influences on the MMTI target during imaging.

Since they are static, none of the ancillary targets used for the polarimetric SAR collection are suitable for MTI purposes. For Ground MTI (GMTI) targets, again GPS and accelerometer instrumentation add to the ancillary data of the target. Without any obvious source of vehicles in the area to co-opt, rental vehicles are the preferred source of control targets. Due to the remoteness of the West Coast of Vancouver Island, availability of rental vehicles is low, so the logistics dictate that the GMTI component of the trial should take place close to the operations at Comox.

Since the MTI data is concerned primarily with instrumented control targets, the MCTS data that was so valuable to the polarimetric collection does not have a major role in defining the MMTI requirements. Therefore, the ability of the CF to digitally record Naval operations in its training area, the Canadian Forces Maritime Experimental and Test Ranges (CFMETR), in the Strait of Georgia provides a suitable opportunity for an MMTI collection of military surface vessels with sufficient instrumentation of their movements.

Thus, three MTI flights can be planned. One MMTI flight is to be centred on the *Cape St. James* in proximity to the ODAS buoy so it can supply environmental data. One GMTI flight is to be centred on rental vehicles operating near Comox. And a final MMTI flight is to be centered on the CFMETR. In each case, differing target course and speed are to be provided for each collection line, and a number of different sensor geometries are to be

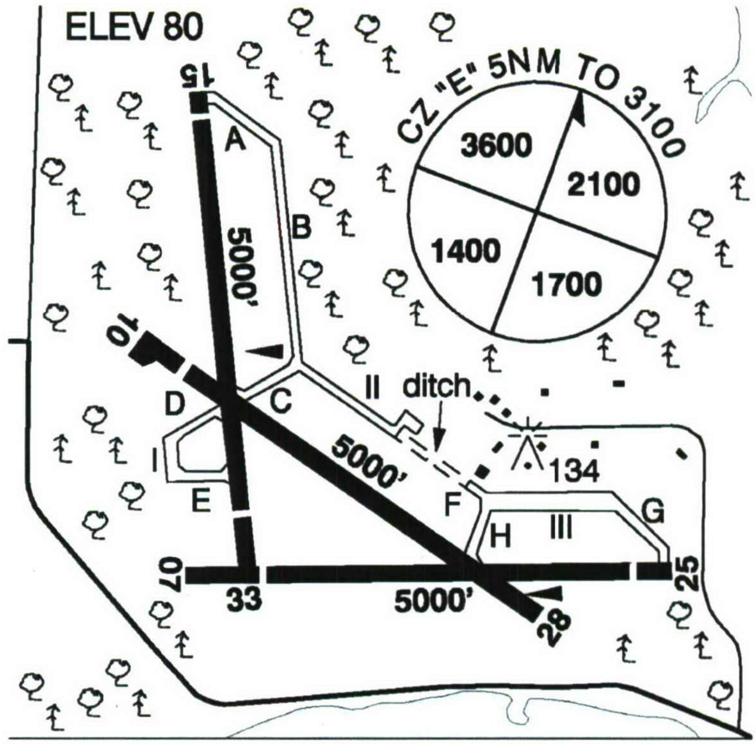


***Figure 3:** Tofino airfield. Main access and public terminal is on the west side (Apron I), while private aircraft and maintenance facilities are accessed from the east (Aprons II and III).*

exercised. At the end of each flight, at least one pass over the calibration site at CYAZ is to be included. For simplicity, a shortened version of one of the 313° T coastal line, or its inverse.

2.3 Calibration Site Requirements

The Tofino airfield has been used previously [10] to deploy SAR calibration equipment. Although on an active airfield, Apron III, between taxiways Hotel and Golf (Figure 3) supports a maintenance facility for private aircraft, and is available for *ad hoc* purposes. Typically, when establishing a calibration site, the natural LOS provide optimal geometries for which to image the site, and thereby govern the deployment of the equipment. However, since the calibration site is a reference point to be acquired in each image line, the local site conditions cannot be fully exploited to enhance the calibration deployment. In fact, it should be expected that some obstacles whose impact could normally be minimized by a change in imaging geometry will be more difficult to overcome. The fact that the calibration site is to be imaged from at least four different directions adds considerable limitations on the deployment of the equipment.

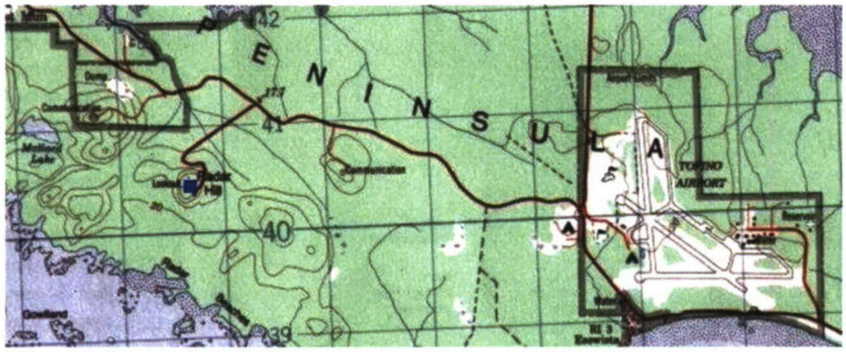


Figure 4: Radar Hill proximity to Tofino Airport. The UTM grid lines are 1 km apart.

The minimum deployment for a calibration site for polarimetric SAR is one CR and one ARC. One Ashtech base station is also required to enable motion compensation for the EC CV-580 platform. To mitigate risk, it is prudent to deploy a second CR, ARC and Ashtech. Since the CRs and ARCs will be imaged, their deployment should be on a low-RCS background and clear of other targets along the range direction, both in near-range (to avoid shadows and side-lobes) and far-range (to avoid layover and allow clear recirculations). Although the Ashtech are not imaged, they do need to have clear LOS to the GPS satellite constellation and an environment clear of clutter that could induce multi-path solutions.

For a trial covering multiple flights, it is desirable to set the equipment up once, powering-up and configuring them immediately prior to the beginning of each day's flight. Thus, having all the equipment in close proximity and easily accessed is a requirement. Security of the equipment and the ability to leave the equipment deployed also factor into the deployment criteria.

It is ideal to have the primary deployment for the Ashtech base stations to be located at a known Survey monument. When continuous deployment over a monument is not reasonable, as often happens on a multiple flight deployment, an effective virtual monument can be established at the primary base station location. This is accomplished outside the CV-580 flights by deploying the secondary base station over an established survey monument and recording a dGPS data set over a sufficiently long collection window. This has been empirically determined to be four hours [11], which includes a large "safety-margin". Since the survey monuments at CYAZ are located on the active runways, these are not suitable for either continuous deployment or establishing a virtual monument. An off-site monument is therefore required. The process for locating a suitable monument is described in Annex D. In this case, a superior monument was located at Radar Hill, approximately 5 km away from CYAZ (Figure 4).

The GPS base stations at CYAZ are suitable for most dGPS purposes required for the CoCoNaut trial, but there was some uncertainty as to the accuracy retained across to the east side of Vancouver Island due to the distances involved. The estimated potential errors were of significant concern only to the GMTI effort. Therefore, an additional Ashtech base station

Table 2: LOS bearing requirements at CYAZ calibration site. The bisection directions characterize an ideal triangular grid that minimizes interference between targets occupying the nodes. All bearings are given in degrees from True North.

<table>
<tr><td>Flight Bearing</td><td>Out</td><td colspan="2">313°</td><td colspan="2">180°</td><td colspan="2">211.5°</td><td colspan="2">313°</td></tr>
<tr><td></td><td>In</td><td colspan="2">133°</td><td colspan="2">0°</td><td colspan="2">31.5°</td><td colspan="2">133°</td></tr>
<tr><td>Look Direction</td><td></td><td colspan="2">43°</td><td colspan="2">90°</td><td colspan="2">301.5°</td><td colspan="2">223°</td></tr>
<tr><td>Reciprocal</td><td></td><td colspan="2">223°</td><td colspan="2">270°</td><td colspan="2">121.5°</td><td colspan="2">43°</td></tr>
<tr><td>Bisection</td><td></td><td></td><td colspan="2">66.5°</td><td colspan="2">105.75°</td><td colspan="2">172.25°</td><td></td></tr>
<tr><td>Reciprocal</td><td></td><td></td><td colspan="2">246.5°</td><td colspan="2">285.75°</td><td colspan="2">352.25°</td><td></td></tr>
</table>

was deployed in Courtney/Comox, a virtual monument established by running a Trimble GPS in base station mode at a superior monument at Campbell River. While the CYAZ base stations were in operation for every flight, these additional base stations were operating only for the benefit of flights supporting the GMTI collections on the east side of Vancouver Island. As such they are mentioned for completeness, but are detailed elsewhere [12].

The deployment of CRs and ARCs is a critical aspect to ensuring the utility of the CV-580 data collected. Previous experience has had success with a 60 m separation between calibration targets [2, 4, 13]. The planned look directions of the SAR sensor imposes clear LOS requirements along the angles 43° T, 90° T, and 101.5° T and their reciprocals. The deployment grid should therefore be laid out along the bisection of these angles, as calculated in Table 2. Fixing the angles of the grid fixes the ratio of distances from a node to its neighbours according to the Law of Sines. In this case, requiring the shortest edge (in the 172.25° T direction) length to be 60 m yields edges of length 86.97 m in the 66.5° T direction and 91.27 m in the 105.75° T direction as shown in Figure 5. Once at the calibration site, the local LOS conditions can be used to optimize the location of the grid and which configuration of CRs and ARCs, deployed on the grid nodes, is most suitable.

2.4 Other Sensors

In addition to the airborne radar and the various ground-truthing sensors, it is desirable to collect imagery of the trial location from Space Based Radar (SBR) sensors. SBR sensors are capable of imaging a much broader swath on the Earth's surface than an airborne SAR can. Unlike airborne SAR, however, SBRs are only able to capture such imagery when the fixed orbit of their satellite platform is within alignment parameters of the desired location. In other words, with an airborne platform, one can designate the place and a time window for the SAR image to be collected while for a SBR, once the place is designated, the SAR image can only be collected at specific instances, typically separated by half a day or more. The orbits of the satellite platforms are deterministic, which allows for the list of possible collection times to be calculated in advance. The planned Commercial Satellite Imagery (CSI) ordered for CoCoNaut is given in Table 3.

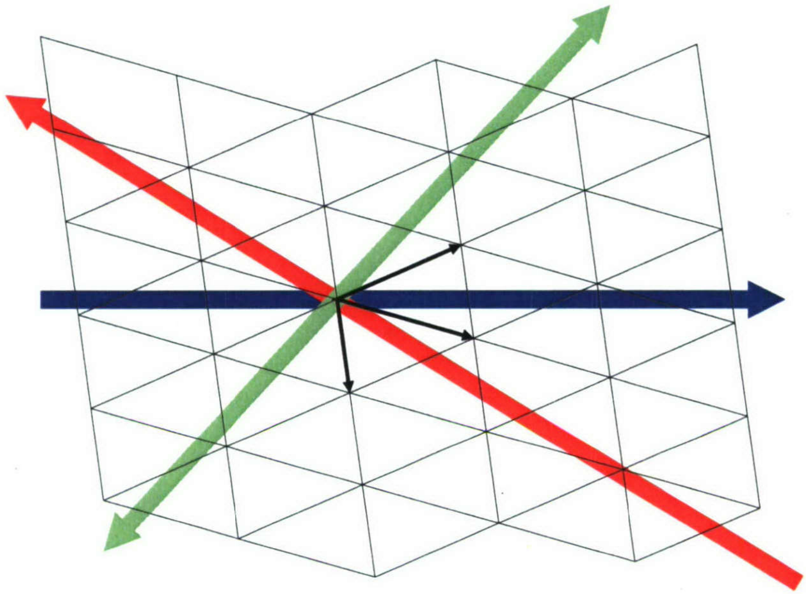


Figure 5: *Triangular grid for calibration site deployment. Planned image line look directions are shown by the coloured swaths: (blue) cardinal line, (red) CYAZ-ODAS line, and (green) coastal line. The bisectors of the look directions, shown by the bold vectors, characterize the triangular grid, namely 66.5°, 105.75°, and 172.25° from vertical, which represents True North.*

Table 3: *SBR CSI collections ordered.*

RADARSAT-1			
Date	UTC Time	Orbit Direction	Mode
22 September 2004	02:25	Ascending	F5F
22 September 2004	14:33	Descending	F1
29 September 2004	02:21	Ascending	F4N
29 September 2004	14:29	Descending	F1
6 October 2004	02:17	Ascending	F1
6 October 2004	14:25	Descending	F4N
23 October 2004	14:38	Descending	F1

ENVISAT				
Date	UTC Time	Orbit Direction	Mode	Polarization
23 September 2004	06:12	Ascending	IS5	AP mode (VV and HH)
26 September 2004	06:18	Ascending	IS7	AP mode (VV and HH)
26 September 2004	18:26	Descending	IS7	AP mode (VV and HH)
29 September 2004	18:31	Descending	IS5	AP mode (VV and HH)
30 September 2004	05:53	Ascending	IS1	AP mode (VV and VH)
2 October 2004	18:37	Descending	IS4	AP mode (VV and HH)

3 Implementation

DRDC Ottawa began deploying on September 16 to Vancouver Island in advance of the CV-580 arrival on September 21 in order to reconnoiter, establish and configure a suitable calibration site, and complete pre-trial ground-truth requirements, including the generation of a virtual monument.

Expectations were high that operations in the Tofino region would be subject to significant amounts of rainfall, as is typically experienced on the west coast of Vancouver Island during the autumn months. Based on a September 17 to October 4, 18 day, schedule, it was expected that 8 days would have some precipitation, and 5 would have at least 5 mm of rain (see annex E). In fact, the only rain encountered occurred at the end of the Sept. 21 workday and lasted through the morning of September 22, a planned day of rest. While the rain did greatly affect one piece of equipment (Subsection 3.2), the general lack of foul weather allowed for the timely completion of the required tasks on the ground.

3.1 Deployment of the Calibration Site

Upon arrival at the Tofino Airport, an area of Apron III was allocated for the calibration site by airport personnel who issued a Notice to Airmen (NOTAM) to avoid equipment in the allocated area. The assigned area lay immediately East of the aircraft/helicopter refueling depot across from the end of Taxiway Hotel. It excluded the access route from the depot along the north edge of Apron III used to exit the airfield through a gate in the fence midway along that edge. Furthermore, private aircraft typically parked along the fenceline near the gate for ease of access. The remainder of the north edge is bordered by a treeline in excess of 5 metres in height. On the infield side, a scrubline of about 2-3 metres in height bordered the eastern third of Apron III, cut in diagonally to the middle of the infield before running west almost to Taxiway Hotel. At the west end of the infield, a weather station tower added further obstructions in its vicinity. The requirement to keep clear LOS over these border obstacles severely restricted the viable locations for the placement of calibration equipment, as shown in Figure 6. Note that pools of water in the infield are evident, reducing the suitability of that area for consistent target to clutter (TCR) measurements.

Fitting the planned grid defined in Section 2.3 with a minimum 60 m spacing between occupied nodes and clear LOS above the foliage surrounding Apron III proved to be unachievable. Following an *ad hoc* risk assessment by the on-site Scientific Authority, which included estimates of typical pixel spread from side-lobes of the CRs and ARCs in previous PolSAR data, a reduced-scale grid with minimum node spacing of 30 m was implemented. While this reduced spacing proved sufficient among the calibration equipment, the impact of having a saturated distributed target in the grid, namely the cube van from which the calibration site team conducted daily operations, was not accurately considered. For some geometries, side-lobes associated with the cube van overlapped those of a CR, invalidating the use of such data for calibration purposes. The placement of the cube van was a calculated risk. It's inclusion in the calibration grid is preferred as a known control target, as well as offering a shelter for the team in close proximity to the equipment. The possibility

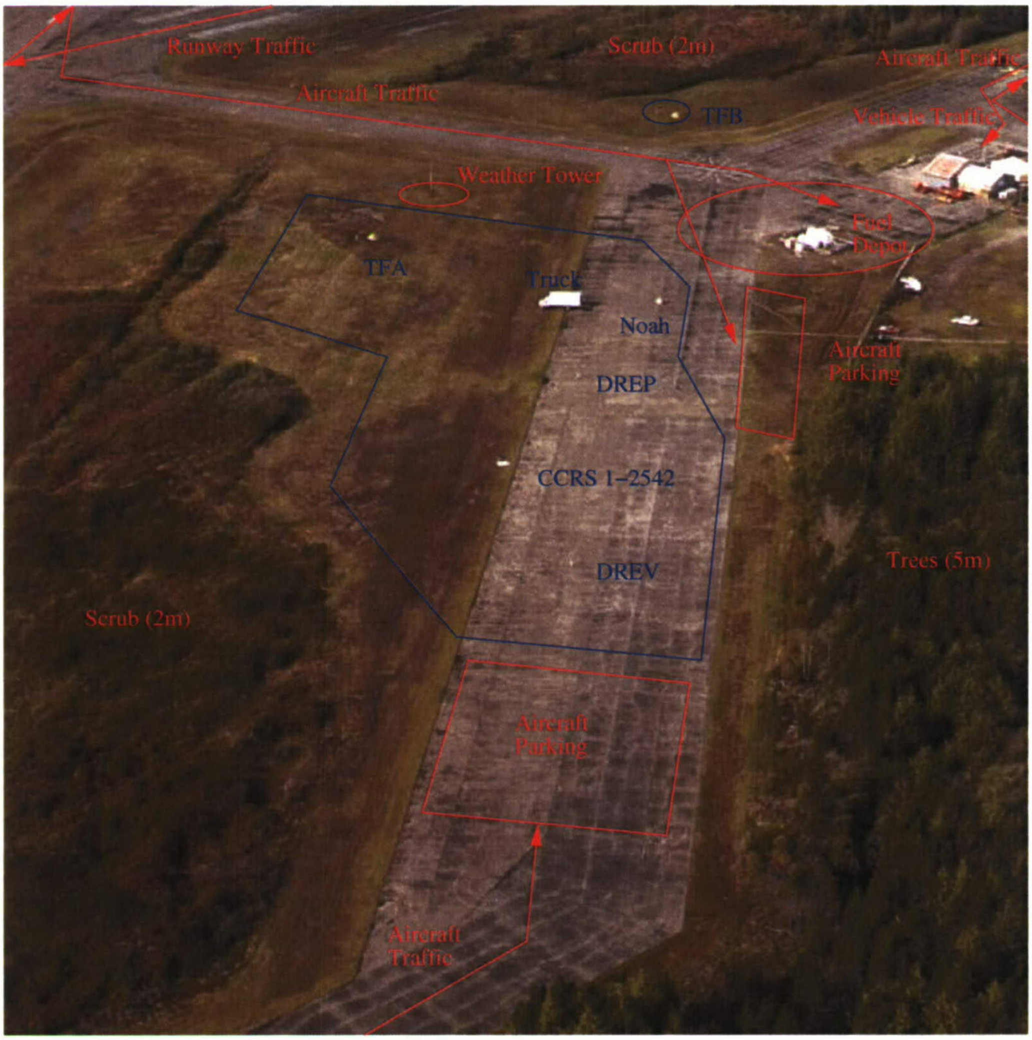


Figure 6: *Deployment area on Apron III allocated for calibration equipment. The red areas and paths show regions where normal airport activity occurs. The blue area delineates the area deemed usable for deployment of the equipment. (Photo by Janice Lang.)*

of positioning the van against the treeline off the north side of Apron III was considered, which would have reduced the risk of interfering with the calibration equipment, but would have guaranteed that the van could not be used as a control target in most of the imagery.

Once the locations for the calibration equipment were determined, the Ashtech base stations could be positioned. Since they only need clear LOS and not a high contrast background, the infields were found to be quite suitable. However, even with this relaxed condition, sufficient room for only one base station with the original 60 m separation. Permission was obtained to deploy the secondary base station on the other side of taxiway Hotel in that infield area.

3.2 Equipment

The CRs and ARCs were deployed at alternating nodes from West to East, the first three linear, with the last node moved back onto the apron rather than further into the infield. The choice of alternating ensures the largest minimum distance between equipment of the same type, limiting the opportunity for something going wrong at one location to affect the other one. The deployment of the two CRs, named DREP and DREV, were done in accordance with standard tripod deployments [10]. ARC CCRS 1-2542 was also deployed according to standard practice [11]. As the remaining ARC, named Noah, is a new experimental design and was only on its third deployment, standard practices have yet to be developed and deployment conditions have not yet been fully envisioned or exercised.

The design of Noah employs three independently deployed components wired together: the Horn assembly, the GPS antenna and the control station [14]. In both prior deployments [2, 4], the requirements have been to point the horns in one azimuth only, and only adjust for elevation. This allowed the components to be housed in a tent, with the components fixed in place relative to the tent, the horns pointing out one door and access to the control station through the other. For the CoCoNaut trial, which required the horns to be pointed in four separate directions and the ability to rapidly switch from one orientation to another between passes of the CV-580, several of the design decisions created obstacles.

First, the GPS antenna was unable to be deployed within 1 m of the horns as its height would interfere with the rotation and LOS of the horns. But by placing the antenna at a large offset from the horns, the utility of having a co-located GPS is lost. Ideally, the GPS antennae should be mounted coaxially with the horn assembly, and the elevation of the horns stopped to keep the antennae from interfering with the LOS of the horns.

Second, the control station, when opened for operation, extended a box lid and laptop screen into a position that would also interfere with the rotation and LOS of the horns. Closing the control station lid during operations to allow for horn rotation would have risked having the laptop datalogger shutdown inappropriately during time-critical operations. The box lid was therefore removed and the laptop screen adjusted appropriately. It would be preferable to have the active horn/GPS assembly mounted outside the tent on a tripod, while the datalogger remained housed in the tent. This would be consistent with the procedures

used to deploy the Ashtech base stations. To do this, sufficient weather-proofing of the externally deployed equipment will be required.

Third, the supplied T_X/R_X cables were inadequate to allow for operational rotation of the horn assembly. The lengths of the cabling were inadequate to allow even 180° rotation. Since no more than two of the four directions were planned for any given day, different cabling configurations were implemented accordingly to allow sufficient latitude to achieve each day's requirements. Part of the cabling difficulty comes from the tendency to wrap around the horn assembly during rotation. A design that brought the cabling up through a hollow axle along the axis of rotation could eliminate this difficulty.

A more serious concern arose with respect to the robustness of Noah. As alluded to above, the one day of rain did adversely affect this equipment. Despite being inside a tent and located in the centre of Apron III, which is designed with a slope to prevent water pooling, a significant amount of water entered the control station box and saturated several electronic components. As a result of this flooding, the Noah ARC was rendered nonoperational for the entire data collection on September 23. The use of pelican cases, rather than wooden boxes, is therefore strongly recommended when designing deployable equipment housing electronics.

Lack of redundancy for meeting power requirements was a cause for equipment failures at a critical time during the September 25 collection. Twelve-volt automotive batteries are typically purchased local to trial deployments since shipping them as equipment requires hazmat procedures. The power requirements for ARCs and base stations typically draw a deep-cycle drain on each battery and require full recharging between CV-580 flights.

At Tofino, recharging was arranged off of a power feed from the maintenance facilities at the end of Apron III. Normally, a full recharge requires as long as the time it took to discharge, in this case 5–6 hours. However, after as little an hour of recharging, the voltage may reach the required level for the recharger indicator to show green, meaning above 75% of voltage. For deep-cycle use, this does *not* mean that the battery has recovered that much capacity. On the 25$^{\text{th}}$, the overnight recharging of the batteries had unknowingly been interrupted by the shut-down of the maintenance shed, after the power feed had been moved to a different outlet. This event was not recognized since the power was restored upon the start-up of the day's operations. Enough recharging had occurred before shut-down and after start-up to have green indicators across all four batteries.

As such, the batteries were deployed without sufficient capacity to complete the day's operations. The schedule was for 8 MMTI passes over a maritime target, followed by 2 passes of the calibration site. First, lack of power cause the Noah control station to shut down. Due to the previous difficulties with the equipment, identifying the cause was not straight-forward. As the final MMTI line was being collected, a battery alarm was noticed sounding at the primary Ashtech base station, indicating imminent shutdown of that equipment. When the battery alarm at the secondary base station also sounded, complete loss of dGPS and therefore motion compensation data for the calibration lines was threatened. The arrangement to have only the minimum requirement for 12-volt batteries meant that a battery had to be

removed from a rental vehicle to retain operations of a single base station. Since the secondary base station was in better condition, the primary was allowed to shut-down when its battery gave out. Despite getting access to the rental-vehicle battery before the secondary station went down, the lack of any jumper cables prevented a seamless transition. In order to switch in the charged battery, the GPS receiver had to be shut down and restarted after the switch. This caused two gaps in the base station dGPS data collection: 19:36:05–19:46:25 Coordinated Universal Time (UTC) and 19:56:27–19:58:17 UTC. The first outage unintentionally occurred during Line 8, start of the line being reported at 12:34 PDT (UTC – 7) and completion of the line being reported at 12:44 PDT (UTC – 7). The second occurred just after collecting the centre of Line 9, the first calibration line, immediately following the report at 12:56 PDT (UTC – 7) from onboard the CV-580 that the ARC had been observed. Fortunately, the fourth battery, powering the CCRS ARC, remained functioning throughout. This was the only time that the minimal calibration site requirements — one CR, one ARC, one Ashtech — were not met.

3.3 CV-580 Flights

The CV-580 collected 13 passes on 23 September (Table 4), passes 1 and 2 being short runs, from 10 km north of CYAZ to 30 km south from CYAZ and then back, respectively, passing through the centre of the main DFO creel survey area. Passes 3–7 were collected over Nanoose Bay, while passes 8–13 were back south of CYAZ and flown in conjunction with CP-140 ground-truthing support. The latter passes ranged from 65 km to 140 km in length. A planned pass parallel to the coastline, from Amphitrite Point northwest over Estevan Point was dropped to maximize the acquisitions over the fisheries area.

On 24 September, without advanced warning, CCG supplied controlled vessels became unavailable for non-critical tasks, including trial participation, due to job action. As controlled vessels are integral to the MMTI collections, but not for the PolSAR collections, the second PolSAR flight was advanced to the 24th and run without a controlled vessel. The loss of the CCG controlled vessel on the 24th instigated a swap between the *Cape St. James* MMTI and the second PolSAR flight, requiring new flight plans to be filed, and overcoming other delays before the flight could begin. The PolSAR flight on 24 September (Table 4) was shortened in duration, but collected 6 passes southwest from CYAZ, centring on the ODAS 46206 buoy at La Perouse Bank, namely on a bearing of 211.7° T. A seventh pass was collected parallel to the coastline, on a bearing of 313.2° T, from Barkley Sound to beyond Estevan Point, looking seaward, again with the centreline passing through CYAZ. Originally planned to be offshore, looking onto land, this pass was reversed to be looking seaward, thereby replacing the coastline pass dropped on the 23rd flight. Additional details on the PolSAR CV-580 flights are presented in Annex C.

A replacement vessel for the MMTI collection was procured by commercial rental and outfitted with GPS and pitch/roll equipment for 25 September and the MMTI flight intended to focus on the *Cape St. James* proceeded with the replacement vessel, *Sharp Point*, in proximity to the ODAS buoy at N 48° 46, W 125° 55'. Eight lines were collected over the *Sharp Point*, which was moving at speeds between 10 and 20 knots, followed by two

Table 4: *Flight acquisition parameters for September 23 and 24 PolSAR collections.*

Date	Line	Look Dir.	RGD (μs)	Imagery Start				Imagery End			
				Time (UTC)	Aircraft DGPS		MSL (m)	Time (UTC)	Aircraft DGPS		MSL (m)
23-Sep-05	l1p1	270	65.62	17:02:26.8	N 49.1547	W 125.9221	6997.30	17:07:26.5	N 48.7800	W 125.9218	7006.77
23-Sep-05	l1p2	90	65.64	17:15:53.9	N 48.8199	W 125.9198	7011.28	17:21:07.5	N 49.1931	W 125.9197	6947.68
23-Sep-05	l5p3	90	65.10	17:38:23.0	N 49.3955	W 124.4264	6912.87	17:44:19.0	N 49.3961	W 123.7319	6913.15
23-Sep-05	l6p4	270	65.06	17:51:20.2	N 49.4861	W 123.8174	6904.34	17:56:24.9	N 49.3213	W 124.2539	6912.84
23-Sep-05	l7p5	270	65.01	18:08:51.6	N 49.2003	W 124.3618	6916.58	18:13:48.2	N 49.2007	W 123.7851	6912.23
23-Sep-05	l8p6	90	65.01	18:22:14.7	N 49.1212	W 123.8250	6918.60	18:27:41.9	N 49.2976	W 124.2934	6912.31
23-Sep-05	l5p7	90	64.95	18:36:56.7	N 49.3317	W 124.2837	6895.26	18:42:29.2	N 49.3307	W 123.6282	6897.91
23-Sep-05	l1p8	270	65.15	19:14:07.3	N 49.2844	W 125.9240	6925.48	19:26:49.2	N 48.3317	W 125.9163	6940.57
23-Sep-05	l1p9	90	65.15	19:37:46.5	N 48.3563	W 125.9162	6949.34	19:49:08.5	N 49.1888	W 125.9192	6930.35
23-Sep-05	l1p10	270	65.13	20:03:24.0	N 49.3988	W 125.9226	6919.43	20:20:24.8	N 48.1144	W 125.9077	6948.49
23-Sep-05	l1p11	90	65.18	20:30:52.8	N 48.5402	W 125.9236	6945.29	20:39:50.2	N 49.1787	W 125.9232	6937.79
23-Sep-05	l1p12	270	65.18	20:50:49.6	N 49.3223	W 125.9186	6934.79	20:58:34.3	N 48.7380	W 125.9201	6942.03
23-Sep-05	l1p13	90	65.18	21:04:36.0	N 48.5579	W 125.9196	6947.01	21:12:55.7	N 49.1568	W 125.9205	6942.85
24-Sep-05	l1p2	90	61.97	19:59:32.7	N 49.1805	W 125.4925	6984.16	20:16:00.4	N 48.2613	W 126.3471	6987.51
24-Sep-05	l1p3	270	61.98	20:23:30.1	N 48.3940	W 126.2329	6977.06	20:34:31.0	N 49.1120	W 125.5613	6966.76
24-Sep-05	l1p4	90	61.97	20:45:47.9	N 49.1336	W 125.5356	6981.63	21:01:27.3	N 48.2590	W 126.3479	6986.22
24-Sep-05	l1p5	270	61.95	21:09:13.7	N 48.4607	W 126.1622	6970.02	21:19:56.1	N 49.1591	W 125.5118	6962.85
24-Sep-05	l1p6	90	62.01	21:30:15.1	N 49.1312	W 125.5398	6981.39	21:44:55.0	N 48.3144	W 126.2993	6983.29
24-Sep-05	l1p7	270	61.98	21:53:34.5	N 48.4953	W 126.1388	6969.09	22:03:50.4	N 49.1585	W 125.5165	6958.21
24-Sep-05	l2p8	270	62.05	22:19:30.4	N 48.8879	W 125.2830	6986.81	22:34:56.9	N 49.6558	W 126.5468	6961.26

calibration lines over CYAZ, both looking inshore [15].

For 27 September, MMTI collections were conducted over the CFMETR in the Strait of Georgia against controlled, instrumented CF and CCG vessels, centred at N 49° 18 38", W 123° 57 12". Seven lines were planned over the maritime targets, however a tape recorder problem required line 5 to be repeated [16]. A transit line parallel to the Vancouver Island Coast was flown to acquire vessels of opportunity. This was followed by a two calibration line over CYAZ, this time both were looking offshore [15].

For 28 September, three transit lines over central Vancouver Island highways were flown for targets of opportunity, five planned GMTI acquisitions of controlled, instrumented vehicles on logging roads near Comox (centred at N 49° 44 28", W 125° 14 00") were collected with two of them repeated due to recorder difficulties on the aircraft [16], and one calibration line over the CYAZ calibration site was collected [15].

3.4 Targets

Most of the expected targets for the PolSAR experiments were vessels of opportunity out at sea and were uncontrolled. On 23 September, with images collected in a swath envelope due south of CYAZ, the MCTS reported 9 vessels whose tracks intersected with the swath envelope between the imaging start and end times of the CV-580 flight. Another 3 vessels had tracks inside the envelope with timestamps less than 30 minutes before or after the imaging times. In addition, aerial photography from the West Coast Wild Adventures (WCWA) platform correlated with 4 of the MCTS contacts, plus 3 additional vessels in the swath envelope south of CYAZ. Also, a single controlled vessel, the *Cape St. James*, operated at pre-determined courses and speed as per the trial plan, remaining within approximately a 5 km radius of the point N 48.893636 W 125.828230. The *Cape St. James* was fully equipped with GPS and pitch/roll sensors recording the ship's motion at a frequency of 2 Hz.

Several of the swaths acquired extended well north of CYAZ, thereby including parts of Clayoquot Sound. In this region, the WCWA aerial photography located a tug towing a floating house and 3 fish farms that could appear in the imagery. Additional details of all these targets can be found in Annex K.

Five of the imagery lines, namely passes 3–7, were acquired over Nanoose Bay. Any information on targets of opportunity during these collections is outside the scope of data collected for the CoCoNaut trial. Annex H contains further details of the imagery collected over Nanoose Bay.

It is highly likely that further detectable targets appear in the CV-580 imagery, but are not accounted for by the above sources. Additional information may be obtained from archives generated by the RMP for that day, or from a CP-140 flight over the area that coincided with passes 8–13.

For the 24 September acquisitions, targets of opportunity in and around the swath envelope

were again tracked by MCTS, yielding 5 tracks intersecting the imaging region between start and stop of imaging. Two additional tracks were in the La Perouse Bank swath region with timestamps less than 30 minutes before or after the imaging times. WCWA aerial photography located 3 of the MCTS tracked vessels and recorded 10 further vessels of opportunity in the area. Although no CP-140 flight occurred on the 24th, the DFO Provincial Airlines (PAL) creel survey did fly, locating the same 3 MCTS tracked vessels as WCWA, along with at least 5 of the additional vessels on the WCWA list. The PAL did overfly up to 6 more vessels in the area of interest. Although no evidence exists to pair up any of the unmatched WCWA and PAL targets, it cannot be ruled out that such matches remain unresolved.

For the final pass along the coast, MCTS tracked 1 target of opportunity in the swath at the time of imaging pass 7 and 1 target as being in the swath at other times during the day's flight. In addition to 5 vessels from the WCWA and PAL aerial photography that were located in the overlapping region with the above swath envelope, 13 additional vessels were located in the pass 7 swath during the 50 minutes preceding the acquisition. An additional tower buoy was located in Clayoquot Sound by the WCWA flight. While never observed by any of the ground-truthing collections, the TriAxys buoy near Amphitrite Point would also be contained in pass 7, as would all the land-based static targets in Table 1. Further details of the 24 September targets are provided in Annex K.

On 25 September, the MMTI experiment concentrated on the controlled target, *Sharp Point*, in proximity to the ODAS buoy. The *Sharp Point* operated at speeds between 10 and 20 knots and was acquired at various geometries [15].

On 27 September, the MMTI experiment over the CFMETR in the Georgia Strait focused on four Navy vessels and one CCG vessel, the CCGC *Cape Cockburn*. All vessels were instrumented with GPS recorders, with two having pitch/roll equipment employed as well, and were operated at speeds between 5 and 15 knots [12]. A single transit line was flown along the coast of central Vancouver Island for targets of opportunity, in which two such vessels were spotted [16].

On 28 September, the GMTI experimented focused on four controlled trucks traveling on logging roads. All four vehicles were instrumented with GPS and two with pitch/roll sensors. Speeds around 50–70 km/h were attained, depending on whether the vehicle was traveling uphill or downhill. Three transit lines along the Island's highways were flown to look for moving targets of opportunity [15].

For land-based targets during the PolSAR acquisitions, most ground-truthing was restricted to targets in close proximity to the cal-site at CYAZ. The exception to this was collected during an excursion to the Canso 11007 crash site. The path into this site is shown in Figure 7. Here, the mostly intact fuselage was surveyed and found to be lying with an approximate bearing of 225° T on an upward slope of about 15° from horizontal. The wreckage can be seen from the air, as shown in Figure 8.

Further land-based targets of opportunity were observed from the calibration site and noted

Table 5: Details of target PBY-5A Canso 11007.

Specifications [17]:				
Wing Span:	31.0 m		101 ft 8 in	
Length:	19.5 m		63 ft 11 in	
Height:	6.1 m		20 ft	
Wingarea:	130.0 sq m		1,399.4 sq ft	
Empty Weight:	9,484 kg		20,864 lb	
Gross Weight:	15,375 kg		33,904 lb	
Max Weight:	15,411 kg		33,904 lb	
Location (GPS):	UTM Zone: 10U	HAE	Geodetic	MSL
Tail (ground level):	0293956 5440039	8.0 m	N 49° 04’ 43.1” W 125° 49’ 17.1”	27.5 m
Centre (top of wing):	0293945 5440028	15.2 m	N 49° 04’ 43.0” W 125° 49’ 18.5”	34.7 m
Nose (ground level):	0293932 5440039	15.3 m	N 40° 04’ 42.9” W 125° 49’ 19.1”	34.8 m

***Figure 7:** Map showing location of Canso crash site and hiking path into the wreck. The UTM grid lines are 1 km apart.*

Figure 8: *Wreckage of Canso 11007 as seen from the air. (Photo by Janice Lang.)*

in the daily logs (see Annex F). Numerous vehicles were moving around the maintenance building, helicopters and aircraft arriving at the fuel depot, taking off and landing along Runway (R/W) 25/07. Aircraft parking along Apron III near the East Gate also came and went. One major target was a Bombardier Canadair Global Express Jet that was parked at the East end of Apron III for the September 29 and 30 CSA flights. Some photographs of these targets were collected, most without any corresponding GPS measurements.

3.5 Support Data Collections

One of the major issues with respect to trials with multiple sources of data is their synchronization in time. Most time settings will either be in UTC or Local Time. UTC is most often used for data timestamps because UTC is independent on the location of deployment. Equipment operating with UTC therefore does not need to be configured for time. Personnel, on the other hand, operate almost exclusively in Local Time. Sleep, meals and working hours are almost always shifted to local time during deployments.

From a purely theoretical point of view, the format providing the most information is the Complete Local Time with Weekday, Timezone, and Offset to UTC, i.e.,

Year-Month-Day	Day of Week	Hour:Minute:Second	Zone	Offset
2004-09-16	Thu	12:00:00	PDT	(UTC − 7)

Since current standards are concerned with portability and readability, rather than completeness, no standard format provides the complete information [18]. It is therefore unlikely that a single format will suffice for a trials deployment. DRDC furnished equipment may be configured or configurable, but often one must work with the format generated by locally procured equipment or reports which may generate times in local daylight time or local standard time. Similarly, equipment brought from DRDC Ottawa may be operating in Eastern Daylight Time (EDT) or Eastern Standard Time (EST), if not appropriately reconfigured, and any processing of the data back at DRDC Ottawa may be using EDT or EST.

A major problem with operating in a time other than Local Time is that often archival actions are based on the day rather than a finer partition. As shown in Table 6, the Julian Day (JD) incremented at 17:00 PDT (UTC − 7) during CoCoNaut. Archival actions occurring after this time need to be manually overridden on equipment operating on UTC, as was required for several GPS track files, otherwise the files would be named and placed in folders associated with the activities of the following day.

Another time issue arising from the use of GPS is that the atomic time scale implemented by the satellite constellation and ground stations cannot tolerate the introduction of leap seconds. Therefore, GPS time and UTC have an increasing delta between them, enumerating the number of leap seconds since 1980 [19]. During CoCoNaut, GPS time minus UTC was 13 seconds. The time delta is broadcast as part of the GPS navigation message, or almanac. GPS receivers collect and use this information to generate timestamps in UTC to within 1 second of UTC. However, until the receiver obtains the complete almanac, the unit may generate timestamps using an outdated delta, or even $\delta = 0$. During CoCoNaut, the

Table 6: *Time conversions during CoCoNaut trial. Times generated by equipment may include Julian Day (JD), Coordinated Universal Time (UTC), Pacific Daylight Time (PDT), Pacific Standard Time (PST), Eastern Daylight Time (EDT), or Eastern Standard Time (EST).*

Julian Day	UTC	GPS	PDT	PST	EDT	EST
JD	07:00:00	07:00:13	00:00	23:00	03:00	02:00
JD	08:00:00	08:00:13	01:00	00:00	04:00	03:00
JD	09:00:00	09:00:13	02:00	01:00	05:00	04:00
JD	10:00:00	10:00:13	03:00	02:00	06:00	05:00
JD	11:00:00	11:00:13	04:00	03:00	07:00	06:00
JD	12:00:00	12:00:13	05:00	04:00	08:00	07:00
JD	13:00:00	13:00:13	06:00	05:00	09:00	08:00
JD	14:00:00	14:00:13	07:00	06:00	10:00	09:00
JD	15:00:00	15:00:13	08:00	07:00	11:00	10:00
JD	16:00:00	16:00:13	09:00	08:00	12:00	11:00
JD	17:00:00	17:00:13	10:00	09:00	13:00	12:00
JD	18:00:00	18:00:13	11:00	10:00	14:00	13:00
JD	19:00:00	19:00:13	12:00	11:00	15:00	14:00
JD	20:00:00	20:00:13	13:00	12:00	16:00	15:00
JD	21:00:00	21:00:13	14:00	13:00	17:00	16:00
JD	22:00:00	22:00:13	15:00	14:00	18:00	17:00
JD	23:00:00	23:00:13	16:00	15:00	19:00	18:00
JD+1	00:00:00	00:00:13	17:00	16:00	20:00	19:00
JD+1	01:00:00	01:00:13	18:00	17:00	21:00	20:00
JD+1	02:00:00	02:00:13	19:00	18:00	22:00	21:00
JD+1	03:00:00	03:00:13	20:00	19:00	23:00	22:00
JD+1	04:00:00	04:00:13	21:00	20:00	00:00	23:00
JD+1	05:00:00	05:00:13	22:00	21:00	01:00	00:00
JD+1	06:00:00	06:00:13	23:00	22:00	02:00	01:00

Table 7: Time settings for various data sources. During CoCoNaut, $\delta_{GPS} = 13$ *s.*

Ashtech TFA	UTC (GPS – δ_{GPS})
Ashtech TFB	UTC (GPS – δ_{GPS})
Ashtech CWA	UTC (GPS – δ_{GPS})
Ashtech CV-580	UTC (GPS – δ_{GPS})
Noah ground station	UTC (GPS – δ_{GPS})
Digital Camera (Grant)	EDT (UTC – 4), UTC – 11 (Sep 22–26),
Digital Camera (Ryan)	PDT (UTC – 7)
Digital Camera (Janice)	UTC
Trimble GPS	UTC (GPS – δ_{GPS})
Garmin Etrex GPS (Ryan)	PDT (GPS – δ_{GPS} - 7)
Garmin Etrex GPS (Grant)	PDT (GPS – δ_{GPS} - 7)
Garmin 76 GPS (Janice)	UTC (GPS – δ_{GPS})
Roll/Pitch Sensors	EDT (UTC – 4)
Rental Vehicle Clocks	PDT (UTC – 7)
Trial Plan	PDT (UTC – 7)
NEC 20269 Laptop	PDT (UTC – 7)
NEC	PDT (UTC – 7)
Stealth 22348 Laptop	PDT (UTC – 7)
YAZ Weather Report	PST (UTC – 8)
PAL Contact Records	UNIX Time

transmission time for a complete almanac was 12.5 minutes.

While some care was taken to ensure that GPS receiver equipment obtained a complete almanac before recording timestamped data, and therefore correctly calculating UTC, it is possible that a receiver could lose or reset the δ_{GPS} information without providing any warning. Awareness of this 13 second signature should allow data users to identify and understand any time discrepancies that might occur in this manner. In the absence of any such observation, it is expected that all GPS time data is correctly converted to UTC timestamps.

4 Calibration Equipment Settings

The calibration equipment introduces effectively point targets of known behaviour into data which encompasses the location of the calibration site. To use these targets to perform radiometric and polarimetric calibration, the parameters governing the response of the targets to the SAR sensor must be accurately recorded. In Table 8, the two CRs, named DREP and DREV, are listed with their location, the measured Corner Edge alignment relative to Magnetic North, and the elevation of the bottom face of the corner, both the desired and measured values. These measurements were taken at the indicated time of day (PDT) corresponding to the indicated flights. Only the 24 September required that the calibration equipment be realigned during the data collection, since the last line was parallel to the coast while all the previous collections were parallel to the CYAZ-ODAS vector.

The Corner Edge alignment is related to the azimuthal angle of the bore sight of the corner by a shift of 90° and the Magnetic Declination at the CR location, namely,

$$\theta_{\mathrm{edge}} = \theta_{\mathrm{bore}} + 90^\circ - \delta_{\mathrm{mag}},$$

where θ_{edge} is the Corner Edge Alignment in the Table, θ_{bore} is the CR bore site with respect to True North, and $\delta_{\mathrm{mag}} = 19.3164^\circ$ is the Magnetic Declination for CYAZ at the time of the CoCoNaut trial [20].

The Corner Pitch is measured from horizontal and is related to the elevation angle of the bore sight by standard geometry, namely

$$\phi^{\mathrm{CR}}_{\mathrm{pitch}} = \phi^{\mathrm{CR}}_{\mathrm{bore}} - \arctan\left(1/\sqrt{2}\right),$$

with $\phi^{\mathrm{CR}}_{\mathrm{pitch}}$ being the Corner Pitch listed in the Table and $\phi^{\mathrm{CR}}_{\mathrm{bore}}$ being the elevation angle of the bore sight.

For the ARCs, the parameters corresponding to each flight are given in Table 9. Here, the Edge Alignment is identical to that used for the CRs, while the Pitch being measured is perpendicular to the bore sight elevation of the ARC horns,

$$\phi^{\mathrm{ARC}}_{\mathrm{pitch}} = 90^\circ - \phi^{\mathrm{ARC}}_{\mathrm{bore}},$$

where $\phi^{\mathrm{ARC}}_{\mathrm{pitch}}$ and $\phi^{\mathrm{ARC}}_{\mathrm{bore}}$ are the Pitch and bore sight elevation angles of the ARC horns, respectively. Since each ARC has two horns, a transmitter and a receiver, the measurements are recorded for each horn separately, identified as Left or Right as determined by the relative position as one looks down the bore sights into the horns.

The experimental ARC, Noah, is equipped with self-recording sensors to measure the Roll, Pitch and Azimuth of the Horn assembly. The sensitivity and calibration of these sensors is on-going, but the data collected may help determine the utility of this data. Here,

$$\theta_{\mathrm{Noah}} = \theta_{\mathrm{edge}} - 90^\circ,$$

and

$$\phi^{\mathrm{Noah}}_{\mathrm{pitch}} = 90 - \phi^{\mathrm{ARC}}_{\mathrm{pitch}},$$

are expected in the ideal case. Note that the sensor measures a single pitch at the centre of the horn assembly rather than across each horn face separately.

The remaining calibration equipment deployed are the GPS basestations used to perform dGPS with the aircraft in order to precisely determine the sensor geometry. Multiple basestations were deployed, both for redundancy and to have a basestations near the imaging sites on each coast. Increasing the distance between the basestation and the imaging area increases errors in the derived imaging geometry. Table 10 provides a set of relevant parameters for five basestation locations. Note that the Radar Hill and CBC Tower locations were operated from known permanent survey monuments in order to establish the locations of the three temporary basestations used for trial purposes.

Table 8: *Corner Reflector Settings*

			DREP		DREV		
		Location (UTM Zone 10U):	0297983 5439811		0298078 5439813		
		Corner Edge	Corner Pitch (degrees from horizontal)				
	Direction	Alignment					
Date-Line	to Aircraft	(Right to Left)	Desired	Measured	Desired	Measured	Time
Sep21-Cal	SW	293.8	-3.9	-2.2	-4.1	-2.3	pre-11:30
Sep23-L1P1	W	340.7	-4.7	-4.8	-4.9	-4.9	pre-09:00
Sep24-L1P1	SE	192.4	-3.7	-3.9	-3.6	-3.7	pre-11:00
Sep24-L2P8	NE	113.8	2.4	2.4	2.6	2.5	15:11
Sep25-L9P9	SW	293.8	-3.9	-3.9	-4.1	-3.7	pre-10:00
Sep27-L9P10	NE	113.8	-3.8	-3.8	-3.7	-3.9	10:03
Sep28-L7P7	NE	113.8	-3.8	-3.7	-3.7	-3.8	12:07
Sep29-Cal	SW	293.8	-3.9	-4.1	-4.1	-3.9	11:58
Sep30-Cal	SW	293.8	-3.9	-4.1	-4.1	-4.1	11:40

Table 9: *ARC Settings*

			CCRS 1-2542			Noah						
		Location (UTM Zone 10U):	0298031 439796			0297936 5439826						
		ARC Edge	ARC Pitch (degrees from horizontal)									
	Direction	Alignment		Measured			Measured					
Date-Line	to Aircraft	(Right to Left)	Desired	Left	Right	Desired	Left	Right	Roll	Pitch	Azimuth	Time
Sep21-Cal	SW	293.8	58.7	57.5	57.4	58.6	57.2	57.2	N/R	N/R	N/R	pre-11:30
Sep23-L1P1	W	340.7	59.5	59.7	59.9	59.3	Offline					pre-09:00
Sep24-L1P1	SE	192.4	58.4	58.4	58.4	58.6	58.5	58.5	N/R	30.1	103.3	pre-11:00
Sep24-L2P8	NE	113.8	52.2	52.4	52.6	52.4	52.4	52.3	N/R	N/R	N/R	by 15:15
Sep25-L9P9	SW	293.8	58.7	58.7	58.6	58.6	Offline					pre-10:00
Sep27-L9P10	NE	113.8	58.5	58.5	58.4	58.6	58.7	58.7	N/R	30.0	21.1	10:37
Sep28-L7P7	NE	113.8	58.5	58.8	59.0	58.6	58.7	58.6	2.0	29.9	21.2	12:05
Sep29-Cal	SW	293.8	58.7	58.7	58.7	58.6	58.7	58.7	1.0	30.0	204.6	12:11
Sep30-Cal	SW	293.8	58.7	58.9	59.2	58.6	58.5	58.2	1.2	30.0	203.0	11:46

Table 10: *Ashtech GPS basestation Settings*

Location Code	TFA	RHA	TFB	CWA	CRA
Date / Day Code	2004-09-18 A	2004-09-18 A	2004-09-21 B	2004-09-27 F	2004-09-29 H
Location	Tofino Airport — Primary	Radar Hill	Tofino Airport — Secondary	Coast Westerly Hotel — Comox	CBC Tower — Campbell River
Latitude	49:04.64146 N	49:05.04362 N	49:04.67798 N	N/R	50 03 12.0829 N
Longitude	125:46.05542 W	125:50.47816 W	125:46.16019 W	N/R	125 19 34.9851 W
Altitude (HAE)	15.81 m	122.88 m	19 m	N/R	170.38 $\pm$1.0
Survey Monument ID	N/A	867010	N/A	N/A	987013
Ashtech Receiver ID	23134	23133	23133	CCRS	Trimble
Antenna ID	S/N 10134	23133	23133	CCRS	Trimble
PC Logger ID	20269	22348	22348	CCRS	Trimble
Slant Height / slot letter	1.3005 m A 1.3005 m E	127.45 cm G 127.40 cm A 127.45 cm D	N/R	1.03 m (1.017 m height)	+1.0 m (above marker)
Horizontal Offset	0.1737 m	0.1737 m		0.1737 m	0
Weather Comments	Partly cloudy, 14° C		Cloudy 12–15° C		

5 Polarimetric Data Set

5.1 Initial PolSAR Analysis

Twenty flight lines of polarimetric data were collected during CoCoNaut on 23 and 24 September 2004. On 23 September, the observation opportunities included an operating submarine in Nanoose Bay (5 lines) and vessels of opportunity and the cooperating vessel CCGC *Cape St. James* offshore from Tofino. On 24 September, the observation opportunity was restricted to vessels of opportunity offshore from Tofino. Each line flown off Tofino included the calibration site that was setup at Tofino airport.

All data have been processed using the PolSAR data processor known as the Configurable Airborne SAR Processor (COASP) that was developed at DRDC Ottawa. To date, only the images acquired on 23 September can be used for data analysis since a problem with the Exciter/Receiver Unit (ERU) plagues the processing of the 24 September data [21]. Some data processing and QC results are summarized in Table 11.

A dGPS system to acquire the ship location during the trial was deployed on the *Cape St. James* so that the vessel velocity and heading could be obtained from the dGPS data. The vessel activities on 23 September are summarized in Annex G.

Initial analysis results are presented in this section. More results will be published as part of an ongoing synthesis of PolSAR data sets of maritime targets. So, for current purposes, we focus on flight line 1 pass 8 (l1p8) of 23 September 2004.

The incidence angle at *Cape St. James*, was 47° looking left. The aircraft flew along a track of 180° T with a ground speed of 140 m/s at an altitude of 6.93 km (see Table 4). The CCG ship was moving with a bearing of 0° T (South to North) and a speed of about 10 m/s. The geometry of the acquisition is illustrated in Figure 9(a); a photograph of the vessel is shown in Figure 9(b). The sea state was very calm and the winds very light during data acquisition.

5.2 Calibration Site

Representative calibration site images from each polarimetric channel, |HH|, |HV|, |VH|, and |VV|, are shown in Figure 10. Two CRs and two ARCs were deployed at the calibration site. However, only one CR and one ARC (as indicated in Figure 10) can be used for image calibration due to constraints of the calibration site (see Section 3.1).

The TCR and the image quality were analyzed using the CR. A TCR value of greater than 20 dB is achieved in the co-polarization channels, as illustrated in Figure 11. The TCR is calculated using the target peak value and the average clutter value for each channel.

The image focus was verified by measuring the 3 dB "width" of the CR response, in azimuth and range, respectively, as shown in Figure 12. Resolutions of about 9 m in ground range and about 1 m in azimuth were achieved for the one-look imagery, indicating that the image is well focused [22].

Table 11: *CoCoNaut Image Analysis Issues. The Sept. 24 lines go from Pass 2 to Pass 8. On the SAR Control Station Data Sheet, the Speed/PRF/Pwr boxes go from Pass 1 to Pass 7. The image formation has been attempted on the assumption that the Pass 1 box is for Pass 2, the Pass 2 box is for Pass 3 etc.*

Date	Line/Pass	SAW	Asar Number	Cal Line Used	Look Direction	Image Reversed PolGASP	Chasp Pro	Image Reversed Chasp1	Comments
23-Sep-05	11p1A	SAW-Out	319	320	PORT	N-S			Image stripped in 2 parts. Cal
	11p1B					N-S			Site covered with corrupted data.
23-Sep-05	11p2	SAW-In	320	320	STARBOARD	NO	YES	E-W	
23-Sep-05	15p3	SAW-In	321	320	STARBOARD	NO	YES	E-W	
23-Sep-05	16p4	SAW-In	322	320	PORT	E-W	YES	NO	
23-Sep-05	17p5	SAW-In	323	320	PORT	NO	YES	NO	
23-Sep-05	18p6	SAW-In	324	320	STARBOARD	NO	YES	unknown	
23-Sep-05	15p7	SAW-In	325	320	STARBOARD	NO	YES	E-W	
23-Sep-05	11p8	SAW-Out	326	326	PORT	N-S	YES	NO	Large image, 246129 lines.
23-Sep-05	11p9	SAW-Out	327						Too much noise. Not processed.
23-Sep-05	11p10	SAW-Out	328	328	PORT	E-W	YES	NO	Large image, 347097 lines.
23-Sep-05	11p11	SAW-Out	329	329	STARBOARD	NO			
23-Sep-05	11p12	SAW-Out	330	330	PORT	E-W	YES	NO	
23-Sep-05	11p13	SAW-Out	331	331	STARBOARD	NO			
24-Sep-05	11p2	SAW-Out	332		STARBOARD	NO			Checkerboard defocus pattern.
24-Sep-05	11p3	SAW-Out	333		PORT	N-S	YES		Checkerboard defocus pattern.
24-Sep-05	11p4		334				YES		Checkerboard defocus pattern.
24-Sep-05	11p5		335				YES		Checkerboard defocus pattern.
24-Sep-05	11p6		336				YES		Checkerboard defocus pattern.
24-Sep-05	11p7		337				YES		Checkerboard defocus pattern.
24-Sep-05	12p8		338				YES		Checkerboard defocus pattern.

(a) (b)

***Figure 9:** (a) Acquisition geometry of CCGC* Cape St. James *for l1p8. (b) Photograph of the* Cape St. James. *(Photo by Janice Lang.)*

5.3 CCGC *Cape St. James*

Representative images of the *Cape St. James* for each polarimetric channel, |HH|, |HV|, |VH|, and |VV|, are shown in Figure 13. The images appear smeared due to ship motion during SAR data acquisition. Therefore, various methods to improve the image focus are applied.

6 Lessons Learned and Conclusions

The CoCoNaut trial, 23 September – 4 October 2004, includes a PolSAR collection component that completes a series of three maritime data collection requirements designed to support and validate the development of polarimetric signature algorithms for ships. The first two collections, Quest-2003 [2] and MarCoPola [4], were obtained in September 2003 and March 2004, respectively. Quest-2003 generated data on a single well-known vessel, the CFAV *Quest*, for which significant electro-magnetic (EM) modeling has been performed [3]. MarCoPola yielded data on the *Quest* operating in tandem with CCG vessels to offer multiple known targets at the same imaging geometry and environment. The CoCoNaut collection expands the types of targets imaged by using targets of opportunity, and collecting as much ancillary ground-truth data about them as possible, in addition to known controlled vessels. In particular, this collection includes several examples of small ships.

In many ways, the series of maritime PolSAR collection trials outstripped the R&D schedule for the algorithms and the image analysis, having all three field trials occur within a single 12 month period. To accomplish this, resources had to be shifted from image processing, analysis and algorithm development to trial planning, deployment and data ac-

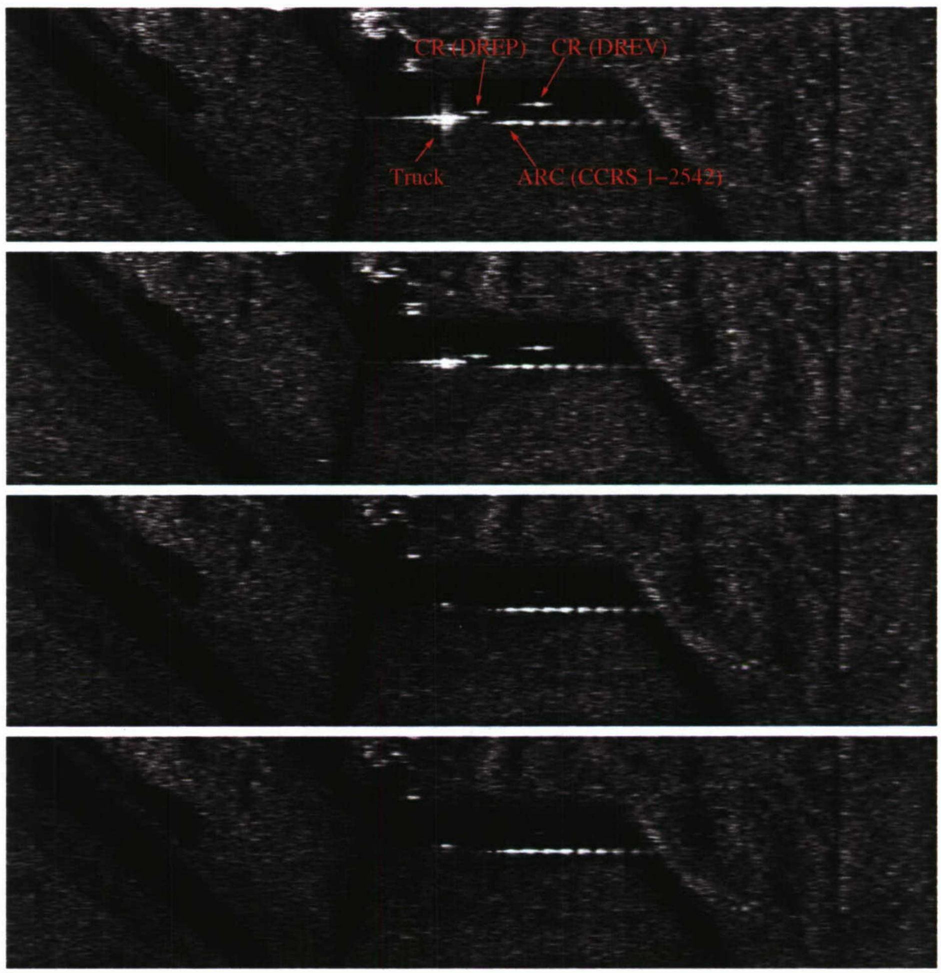


Figure 10: *Images of the calibration site, l1p8, 23 September 2004. From top to bottom are the* $|HH|$*,* $|VV|$*,* $|HV|$*, and* $|VH|$ *channels. The aircraft is flying from north to south down the left side.*

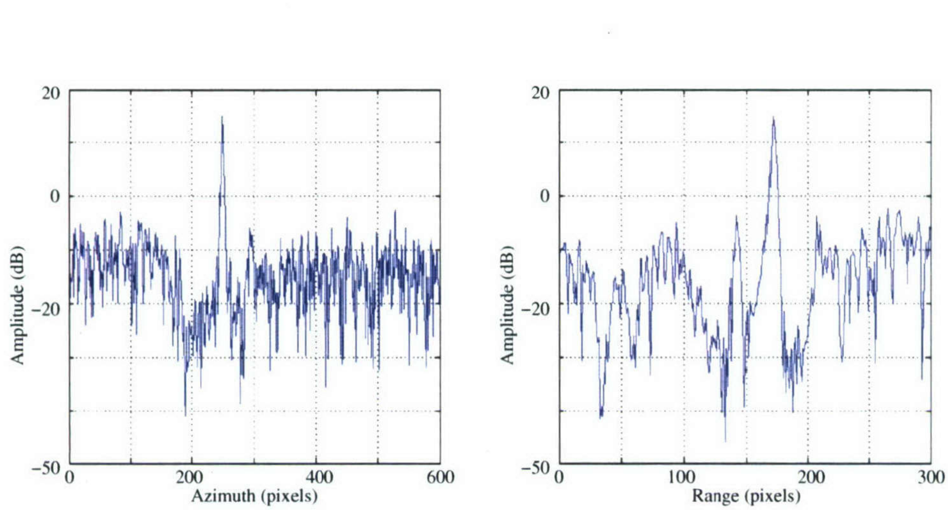


Figure 11: *Illustration of TCR for the CR, I1p8, 23 September 2004, in range (left) and in azimuth (right) for the HH channel.*

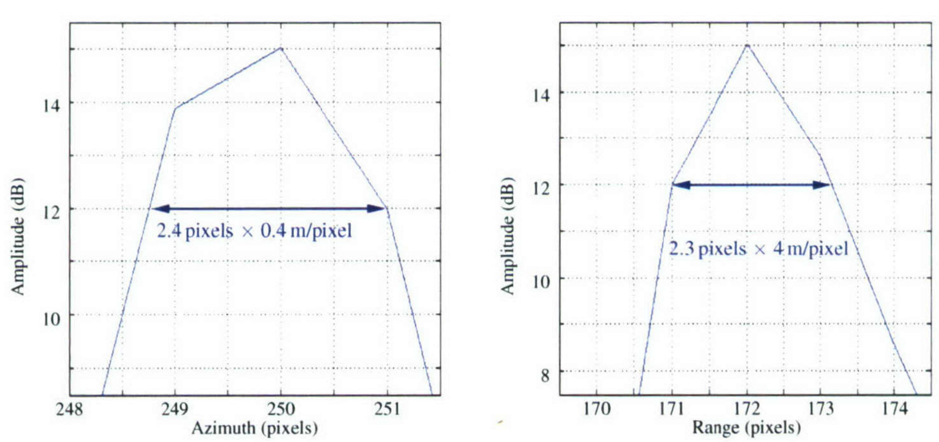


Figure 12: *Illustration of the range (left) and azimuth (right) resolutions for the CR, I1p8, 23 September 2004 for the HH channel.*

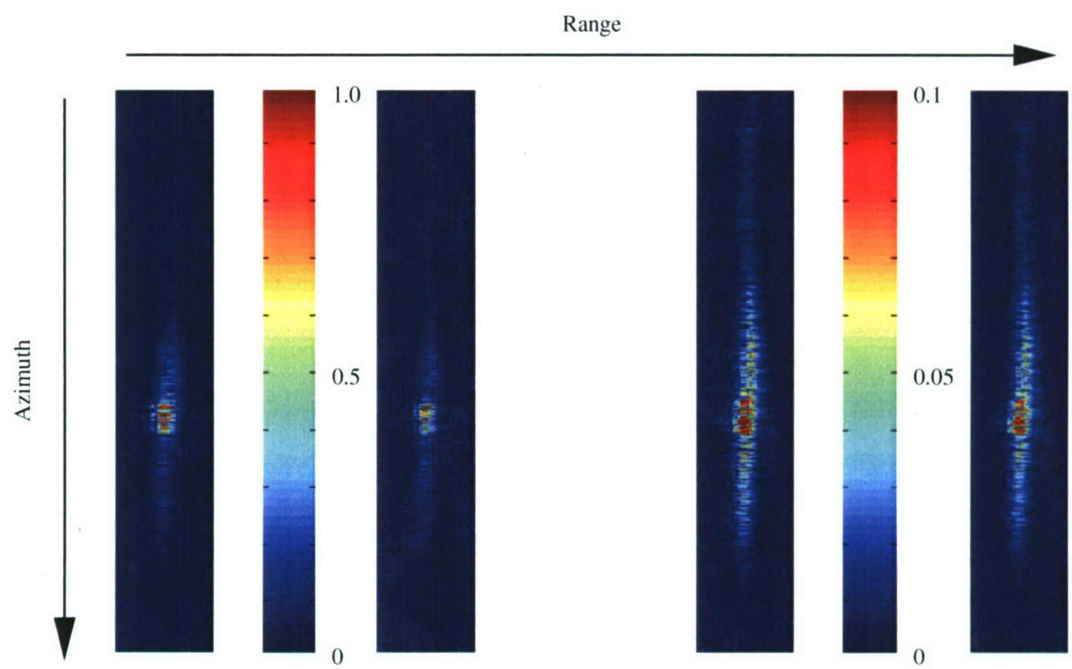


Figure 13: *SAR images of a CCG ship, I1p8, 23 September 2004. From left to right are from* $|HH|$, $|VV|$, $|HV|$, *and* $|VH|$ *channels. The colorbars indicate the amplitude scale of the two co-polarized (left) and two cross-polarized (right) images. The aircraft is flying from north to south down the left side.*

quisition. Although a multi-year R&D plan was intended with field trials synchronized to the development schedule, opportune funding and leveraging against platform deployments drove the aggressive field trial schedule, especially for CoCoNaut, which went from first commitment to deployment in 12 weeks. For a field trial of this magnitude, 18–24 months is the preferred lead time to allow for proper planning and preparation.

The benefits of taking such opportunities is not without cost, however. First and foremost, the planned cycle of analysis, development, data acquisition and validation becomes severely disrupted. More so in this case, because the personnel performing the tasks are, in fact, the same. Not only does the aggressive schedule bring in more data ahead of schedule, but pushes back the tasks on the previous data. We observe that the state of processing and analysis of the CoCoNaut data is no better than would be expected than if the three trials had been scheduled with 12–18 months in between.

As such, the aggressive schedule has introduced artificially large time discrepancies between the data collections and the subsequent analysis and reporting on the collection. These time delays may allow a deterioration in the quality, integrity and relevance of the data collected. There are benefits to keeping data collections on schedule in addition to the timeliness of associated deliverables. Advances in sensors and data collection methods can improve the utility of data; had CoCoNaut been conducted in 2005 or later, support for Automatic Identification System (AIS) collection would likely have been implemented, further improving the quality of the ground truth for targets of opportunity. The better results from one trial are understood, the better plans can be laid for subsequent trials; a fully developed analysis plan for CoCoNaut would have guided the trial design by emphasizing certain targets for both imaging and ground-truthing, and would have made for more timely contributions to project deliverables. All in all, a closer matching of field trial collections to their analysis, application and reporting schedules would be highly desirable.

While great strides have been made in the ability of DRDC Ottawa to plan and deploy for field trials, which has allowed for the increased flexibility and rapidity of response to opportunities, greater coordination with the CF and supporting services is still desirable. Commitments to reconnaissance trips to deployment sites, providing briefings and holding planning meetings with supporting personnel would serve greatly in improving the alignment of expectations, requirements and participation between all involved.

The data collected in CoCoNaut, along with Quest-2003 and MarCoPola, will provide sufficient imagery to develop and validate polarimetric signature algorithms for the CV-580 SAR sensor. Since this sensor is being used as a testbed for RADARSAT-2, additional data collections with coincident CV-580 and RADARSAT-2 acquisitions will be required to validate the testbed results against the operational data. It is advisable that such collections include both targets similar to those collected in this series of field trials, as well as expanding the available target classes to validate the algorithms over even a greater range of potential targets.

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Annex A
Proposal for West Coast SAR Experiments

A.1 Radar Data Exploitation Group Proposal

Proposal for SAR Experiments
September/October, 2004
C. Liu, P. Vachon, R. English
26 July 2004

DRDC Ottawa proposes a joint SAR trial with known ships using the Environment Canada Convair-580 SAR in West Coast during the week of September 27, 2004 (or 4 October 2004). The RDE portion of the trial will consist of two experiments in ONE flight: Polarimetric Signature Collection of a Vessel at Sea and Sea-Truthed False Alarm Collections. The objectives and requirements for each experiment are briefly described below.

Polarimetric Signature Collection of a Vessel at Sea
This experiment is designed to acquire data of the known ships in addition to the collection of Quest 2003 (October 2003) and Marco Pola 2004 (March 2004) and sea-truthed false alarms. These data are critical for

- Dual and quad polarimetric ship detection performance analysis
- Evaluation of algorithms for ship classification
- Determination of the effects of motion on polarimetric signatures
- Ship velocity estimation

The requirements are:

Option 1 — NO COOPERATING VESSELS

- Targets of opportunity are imaged repeatedly while flying a box pattern over the selected maritime area.
- During the radar passes, additional air-truthing of nearby ships should be recorded. This should include ship position, heading and speed
- Contact Canadian Coast Guard to identify the buoy locations which may be in the trial area so the ships could be active in these areas
- Acquire data synchronizing with RADARSAR-1 and ENVISAT passes, as available. Exact acceptable range of heading and date of overpass of region of concern when orders for the imagery are planned.

Option 2 — COOPERATING VESSEL AVAILABLE (funding dependent):

- Ships should be steaming along a fixed course, preferably using a different speed for each of the aircraft passes (one speed should be zero). Aircraft dwell time is three to four hours and the number of passes will number approximately six.
- During the radar passes, the ships position, heading, and speed should be recorded along with 3-axis accelerometer data.

- (no directional wave spectra equipment available)
- During the radar passes, additional truthing of nearby ships should be recorded. This should include ship position, heading and speed
- Contact Canadian Coast Guard to identify the buoy locations which may be in the trial area so the ships could be active in these areas
- Acquire data synchronizing with RADARSAR-1 and ENVISAT passes, as available. Exact acceptable range of heading and date of overpass of region of concern when orders for the imagery are planned.

Sea-Truthed False Alarm Collections
To support Automatic Target Detection/Recognition development, it is necessary to obtain sufficient sea-truthing to distinguish between targets (i.e., ships) and common sources of false alarms (breaking waves, reefs, icebergs, etc.) in a wide variety of imagery.

The experiment requirements are to:

- To locate and identify any ships within the region during the patrol
- To locate and identify any non-ship objects or areas that might be detected as false alarms within the patrol region
- To obtain representative time-stamped/geo-located photographs of ship and non-ship targets in the patrol region

Trial Plan
RDE Funding will allow ONE flight for the trial, with polarimetric mode. The data collected will support both polarimetric signature and sea-truthed false alarm collections. Additionally, the data can be furnished to support other research such as wake and ocean surface observation.

A.2 Space Based Radar Group proposal

Maritime MTI [23]
This experiment is designed to take radar measurements of a known ship at sea to determine the impact of vessel and ocean dynamics on MTI detection.

The experiment requirements are:

- Ships should be steaming along a fixed course, preferably using a different speed for each of the aircraft passes. Aircraft dwell time is three to four hours so the number of passes will be approximately six.
- During radar passes, the ships position, heading, and speed should be recorded along with 3-axis accelerometer data.
- During the radar passes, the wind and wave state should be known, including the directional wave spectrum.
- During the radar passes, additional truthing of nearby ships should also be recorded. This should include ship position, heading and speed.

A.3 Additional DRDC proposal

Ship Wake and Ocean Observation [24]
This experiment is designed to collect ocean surface features. These features include surface/sub-surface ship and ship wake detection. The data from CV-580 are critical for the development and evaluation of algorithms for ship wake detection.

The experiment requirements are:

- Surface vessels operating at cruising speed of between 10 and 15 knots in a constant heading that is 20 to 60 degrees off the radar sensor cross-range; and
- Sub-surface vessel operating at speed of 5 - 10 knots in a constant heading. The submarine should vary speed and direction, to be determined prior to the final version of the experiment plan. The submarine should be submerged for all experiments at a depth of approximately 50 m. The top of the submarine should not exceed 20 m below the surface at any time during the experiment. The submarine should not submerge below 80 m at any time during the experiment.
- Synchronize acquisitions with RADARSAT-1 and ENVISAT passes, as available.
- Vessel position, heading, and speed should be recorded along with 3-axis accelerometer data, if available.
- During the radar passes, the wind and wave state should be known, including the directional wave spectrum.
- During the radar passes, truthing of nearby ships should also be recorded. This should include ship position, heading and speed.
- Ocean density and temperature profiles should be measured during the radar passes.

Annex B
West Coast Vancouver Island Creel Survey

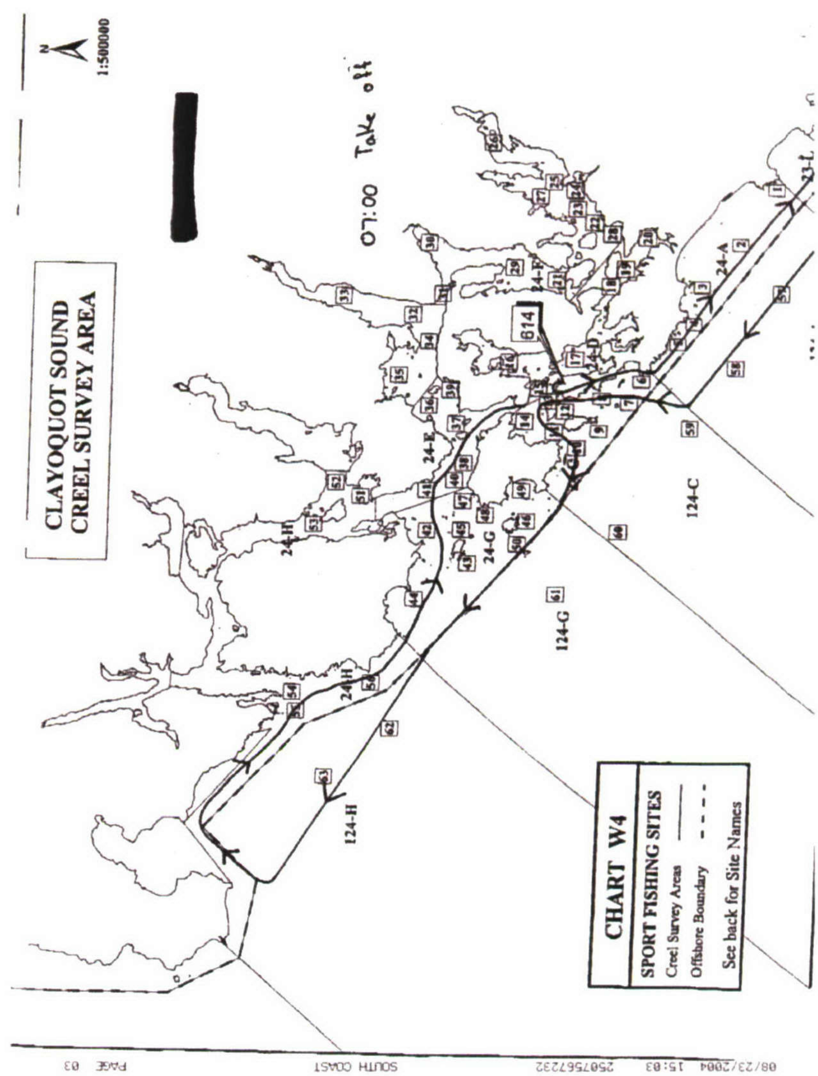

Figure B.1: *FAX from DFO showing Clayoquot Sound creel survey area and nominal flight plan.*

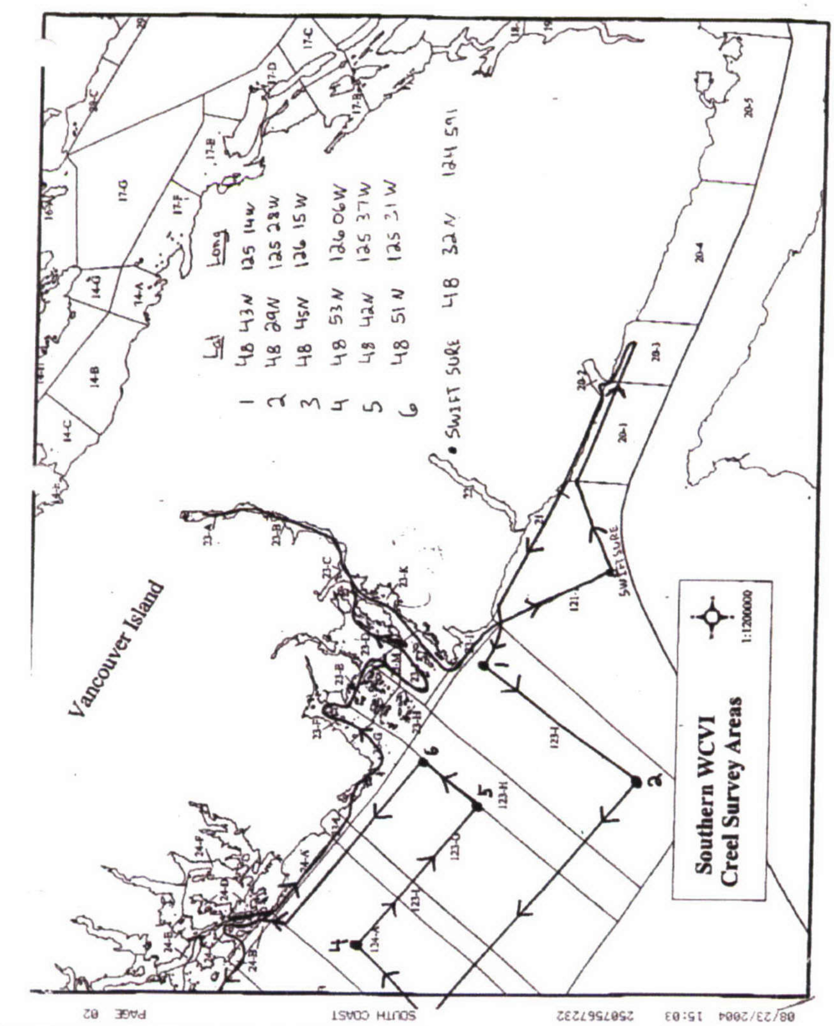

Figure B.2: *FAX from DFO showing Southern West Coast Vancouver Island creel survey areas, nominal flight plan and significant waypoints.*

Annex C
Flight Planning

C.1 Organization

a. The authority for flight planning under this event was Major Ken Craig, 1 CAD MAC (P), A3-1-3 SO Aerospace Coordinator. Mission plans were filed by the 407 Ops cell, where Captain Fletcher Wade was assigned as our point of contact. Captain Wade, as a pilot for 407 Sqn, was instrumental to the success of the work, providing close support to the needs of Bryan Healey, pilot for the Environment Canada CV-580 SAR.

b. During the course of the work, potential conflicts were noted regarding the photo recce flights (West Coast Wild, Tofino Air Lines) , Convair missions and other planned traffic for the airspace. De-confliction notices were sent by Captain Jan Karr, MAC(P) A3-1-3 to David Schlingmeier and forwarded to the pilots for the aircraft supporting our work. The pilots proposed alternatives and resolved the conflicts.

C.2 CV-580 Flight Plan 04D1

```
ALL FLIGHT & SENSOR DATA
========================

Project ID: 04D1   Listing Date: SEP 15, 04

================================================================================

                                       Altitude [AGL]            22000.0  ft
 Flight ID                           L1

                         Flight Line   Track             Image Line    Track
                                       [deg]                           [deg]
 RunIn          N49:28:48 W125:55:23   179.9
 ImageStrt      N49:08:48 W125:55:19   179.9   N49:08:48 W125:46:12    180.0
 Target         N48:41:18 W125:55:14   179.9   N48:41:18 W125:46:12    180.0
 ImageEnd       N48:13:48 W125:55:09   179.9   N48:13:48 W125:46:12    180.0
 RunOut         N47:53:48 W125:55:06   179.9
 Length                    95.00  nm                      55.00  nm
 RunI/O Len                20.00  nm
 SENSOR                     C/X/IRIS Nadir
 Swath width                     11.93  nm
 Look direction                      Left
 Look heading                     89.9/E
                            Ground Range    Slant Range   Incid. Angle
 Near                            0.00  nm       3.62  nm        0.00 deg
 Centre                          5.97  nm       6.98  nm       58.75 deg
 Far                            11.93  nm      12.47  nm       73.12 deg
================================================================================

                                       Altitude [AGL]            22000.0  ft
 Flight ID                           L2
```

```
                      Flight Line       Track            Image Line     Track
                                        [deg]                           [deg]
RunIn         N47:53:48 W125:55:06      359.9
ImageStrt     N48:13:48 W125:55:09      359.9   N48:13:48 W125:46:12      0.0
Target        N48:41:18 W125:55:14      359.9   N48:41:18 W125:46:12      0.0
ImageEnd      N49:08:48 W125:55:19      359.9   N49:08:48 W125:46:12      0.0
RunOut        N49:28:48 W125:55:23      359.9
Length                  95.00  nm                        55.00  nm
RunI/O Len              20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                   11.93  nm
Look direction                    Right
Look heading                     89.9/E
                         Ground Range    Slant Range   Incid. Angle
Near                          0.00  nm      3.62  nm       0.00 deg
Centre                        5.97  nm      6.98  nm      58.75 deg
Far                          11.93  nm     12.47  nm      73.12 deg
================================================================================

                                        Altitude [AGL]          22000.0  ft
Flight ID                          L3

                      Flight Line       Track            Image Line     Track
                                        [deg]                           [deg]
RunIn         N49:28:48 W125:55:23      179.9
ImageStrt     N49:08:48 W125:55:19      179.9   N49:08:48 W125:46:12    180.0
Target        N48:41:18 W125:55:14      179.9   N48:41:18 W125:46:12    180.0
ImageEnd      N48:13:48 W125:55:09      179.9   N48:13:48 W125:46:12    180.0
RunOut        N47:53:48 W125:55:06      179.9
Length                  95.00  nm                        55.00  nm
RunI/O Len              20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                   11.93  nm
Look direction                     Left
Look heading                     89.9/E
                         Ground Range    Slant Range   Incid. Angle
Near                          0.00  nm      3.62  nm       0.00 deg
Centre                        5.97  nm      6.98  nm      58.75 deg
Far                          11.93  nm     12.47  nm      73.12 deg
================================================================================

                                        Altitude [AGL]          22000.0  ft
Flight ID                          L4

                      Flight Line       Track            Image Line     Track
                                        [deg]                           [deg]
RunIn         N47:53:48 W125:55:06      359.9
ImageStrt     N48:13:48 W125:55:09      359.9   N48:13:48 W125:46:12      0.0
Target        N48:41:18 W125:55:14      359.9   N48:41:18 W125:46:12      0.0
ImageEnd      N49:08:48 W125:55:19      359.9   N49:08:48 W125:46:12      0.0
RunOut        N49:28:48 W125:55:23      359.9
Length                  95.00  nm                        55.00  nm
RunI/O Len              20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                   11.93  nm
```

```
Look direction                    Right
Look heading                     89.9/E
                            Ground Range    Slant Range   Incid. Angle
Near                            0.00  nm       3.62  nm        0.00 deg
Centre                          5.97  nm       6.98  nm       58.75 deg
Far                            11.93  nm      12.47  nm       73.12 deg
================================================================================

                                     Altitude [AGL]           22000.0  ft
Flight ID                        L5

                       Flight Line   Track            Image Line    Track
                                     [deg]                          [deg]
RunIn         N49:28:48 W125:55:23   179.9
ImageStrt     N49:08:48 W125:55:19   179.9   N49:08:48 W125:46:12    180.0
Target        N48:41:18 W125:55:14   179.9   N48:41:18 W125:46:12    180.0
ImageEnd      N48:13:48 W125:55:09   179.9   N48:13:48 W125:46:12    180.0
RunOut        N47:53:48 W125:55:06   179.9
Length                  95.00  nm                       55.00  nm
RunI/O Len              20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                     Left
Look heading                     89.9/E
                            Ground Range    Slant Range   Incid. Angle
Near                            0.00  nm       3.62  nm        0.00 deg
Centre                          5.97  nm       6.98  nm       58.75 deg
Far                            11.93  nm      12.47  nm       73.12 deg
================================================================================

                                     Altitude [AGL]           22000.0  ft
Flight ID                        L6

                       Flight Line   Track            Image Line    Track
                                     [deg]                          [deg]
RunIn         N47:53:48 W125:55:06   359.9
ImageStrt     N48:13:48 W125:55:09   359.9   N48:13:48 W125:46:12      0.0
Target        N48:41:18 W125:55:14   359.9   N48:41:18 W125:46:12      0.0
ImageEnd      N49:08:48 W125:55:19   359.9   N49:08:48 W125:46:12      0.0
RunOut        N49:28:48 W125:55:23   359.9
Length                  95.00  nm                       55.00  nm
RunI/O Len              20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                    Right
Look heading                     89.9/E
                            Ground Range    Slant Range   Incid. Angle
Near                            0.00  nm       3.62  nm        0.00 deg
Centre                          5.97  nm       6.98  nm       58.75 deg
Far                            11.93  nm      12.47  nm       73.12 deg
================================================================================

                                     Altitude [AGL]           22000.0  ft
Flight ID                        L7
```

```
                    Flight Line    Track              Image Line    Track
                                   [deg]                            [deg]
RunIn         N48:33:41 W125:12:15  313.6
ImageStrt     N48:47:26 W125:34:13  313.3   N48:51:47 W125:28:00    313.4
Target        N49:07:57 W126:07:34  312.9   N49:12:19 W126:01:21    313.0
ImageEnd      N49:28:18 W126:41:23  312.5   N49:32:42 W126:35:10    312.6
RunOut        N49:41:46 W127:04:10  312.2
Length                100.00  nm                      60.00  nm
RunI/O Len             20.00  nm
SENSOR                  C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                   Right
Look heading                   42.9/NE
                         Ground Range    Slant Range   Incid. Angle
Near                          0.00  nm      3.62  nm       0.00 deg
Centre                        5.97  nm      6.98  nm      58.75 deg
Far                          11.93  nm     12.47  nm      73.12 deg
```

C.3 Flight Plan 04D2

```
ALL FLIGHT & SENSOR DATA
========================

Project ID: 04D2   Listing Date: SEP 15, 04

================================================================================

                                  Altitude [AGL]            22000.0  ft
 Flight ID                      L1

                    Flight Line    Track              Image Line    Track
                                   [deg]                            [deg]
RunIn         N49:22:50 W125:18:07  212.0
ImageStrt     N49:05:52 W125:34:18  211.8   N49:09:00 W125:42:03    211.7
Target        N48:40:19 W125:58:14  211.5   N48:43:26 W126:05:57    211.4
ImageEnd      N48:14:42 W126:21:46  211.2   N48:17:47 W126:29:27    211.1
RunOut        N47:57:35 W126:37:15  211.0
Length                100.00  nm                      60.00  nm
RunI/O Len             20.00  nm
SENSOR                  C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                   Right
Look heading                  301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                          0.00  nm      3.62  nm       0.00 deg
Centre                        5.97  nm      6.98  nm      58.75 deg
Far                          11.93  nm     12.47  nm      73.12 deg
================================================================================

                                  Altitude [AGL]            22000.0  ft
 Flight ID                      L2
```

```
                    Flight Line    Track               Image Line    Track
                                   [deg]                             [deg]
RunIn        N47:57:35 W126:37:15   31.0
ImageStrt    N48:14:42 W126:21:46   31.2   N48:17:47 W126:29:27     31.1
Target       N48:40:19 W125:58:14   31.5   N48:43:26 W126:05:57     31.4
ImageEnd     N49:05:52 W125:34:18   31.8   N49:09:00 W125:42:03     31.7
RunOut       N49:22:50 W125:18:07   32.0
Length                100.00  nm                   60.00  nm
RunI/O Len             20.00  nm
SENSOR                  C/X/IRIS Nadir
Swath width                 11.93  nm
Look direction                   Left
Look heading               301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                         0.00  nm      3.62  nm       0.00 deg
Centre                       5.97  nm      6.98  nm      58.75 deg
Far                         11.93  nm     12.47  nm      73.12 deg
================================================================================

                                   Altitude [AGL]            22000.0  ft
Flight ID                      L3

                    Flight Line    Track               Image Line    Track
                                   [deg]                             [deg]
RunIn        N49:22:50 W125:18:07  212.0
ImageStrt    N49:05:52 W125:34:18  211.8   N49:09:00 W125:42:03    211.7
Target       N48:40:19 W125:58:14  211.5   N48:43:26 W126:05:57    211.4
ImageEnd     N48:14:42 W126:21:46  211.2   N48:17:47 W126:29:27    211.1
RunOut       N47:57:35 W126:37:15  211.0
Length                100.00  nm                   60.00  nm
RunI/O Len             20.00  nm
SENSOR                  C/X/IRIS Nadir
Swath width                 11.93  nm
Look direction                  Right
Look heading               301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                         0.00  nm      3.62  nm       0.00 deg
Centre                       5.97  nm      6.98  nm      58.75 deg
Far                         11.93  nm     12.47  nm      73.12 deg
================================================================================

                                   Altitude [AGL]            22000.0  ft
Flight ID                      L4

                    Flight Line    Track               Image Line    Track
                                   [deg]                             [deg]
RunIn        N47:57:35 W126:37:15   31.0
ImageStrt    N48:14:42 W126:21:46   31.2   N48:17:47 W126:29:27     31.1
Target       N48:40:19 W125:58:14   31.5   N48:43:26 W126:05:57     31.4
ImageEnd     N49:05:52 W125:34:18   31.8   N49:09:00 W125:42:03     31.7
RunOut       N49:22:50 W125:18:07   32.0
Length                100.00  nm                   60.00  nm
RunI/O Len             20.00  nm
SENSOR                  C/X/IRIS Nadir
Swath width                 11.93  nm
```

```
Look direction                   Left
Look heading                 301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                         0.00  nm       3.62  nm       0.00 deg
Centre                       5.97  nm       6.98  nm      58.75 deg
Far                         11.93  nm      12.47  nm      73.12 deg
===============================================================================

                                   Altitude [AGL]           22000.0  ft
Flight ID                     L5

                     Flight Line    Track            Image Line    Track
                                    [deg]                          [deg]
RunIn         N49:22:50 W125:18:07  212.0
ImageStrt     N49:05:52 W125:34:18  211.8   N49:09:00 W125:42:03    211.7
Target        N48:40:19 W125:58:14  211.5   N48:43:26 W126:05:57    211.4
ImageEnd      N48:14:42 W126:21:46  211.2   N48:17:47 W126:29:27    211.1
RunOut        N47:57:35 W126:37:15  211.0
Length                  100.00  nm                   60.00  nm
RunI/O Len               20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                   Right
Look heading                 301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                         0.00  nm       3.62  nm       0.00 deg
Centre                       5.97  nm       6.98  nm      58.75 deg
Far                         11.93  nm      12.47  nm      73.12 deg
===============================================================================

                                   Altitude [AGL]           22000.0  ft
Flight ID                     L6

                     Flight Line    Track            Image Line    Track
                                    [deg]                          [deg]
RunIn         N47:57:35 W126:37:15   31.0
ImageStrt     N48:14:42 W126:21:46   31.2   N48:17:47 W126:29:27     31.1
Target        N48:40:19 W125:58:14   31.5   N48:43:26 W126:05:57     31.4
ImageEnd      N49:05:52 W125:34:18   31.8   N49:09:00 W125:42:03     31.7
RunOut        N49:22:50 W125:18:07   32.0
Length                  100.00  nm                   60.00  nm
RunI/O Len               20.00  nm
SENSOR                   C/X/IRIS Nadir
Swath width                  11.93  nm
Look direction                   Left
Look heading                 301.5/NW
                         Ground Range    Slant Range   Incid. Angle
Near                         0.00  nm       3.62  nm       0.00 deg
Centre                       5.97  nm       6.98  nm      58.75 deg
Far                         11.93  nm      12.47  nm      73.12 deg
===============================================================================

                                   Altitude [AGL]           22000.0  ft
Flight ID                     L7
```

	Flight Line	Track [deg]	Image Line	Track [deg]
RunIn	N48:42:18 W124:59:46	313.8		
ImageStrt	N48:56:06 W125:21:45	313.5	N48:51:47 W125:28:00	313.4
Target	N49:16:41 W125:55:07	313.1	N49:12:19 W126:01:21	313.0
ImageEnd	N49:37:05 W126:28:56	312.7	N49:32:42 W126:35:10	312.6
RunOut	N49:50:36 W126:51:45	312.4		
Length	100.00 nm		60.00 nm	
RunI/O Len	20.00 nm			
SENSOR	C/X/IRIS Nadir			
Swath width	11.93 nm			
Look direction	Left			
Look heading	223.1/SW			

	Ground Range	Slant Range	Incid. Angle
Near	0.00 nm	3.62 nm	0.00 deg
Centre	5.97 nm	6.98 nm	58.75 deg
Far	11.93 nm	12.47 nm	73.12 deg

Annex D
Survey Monuments

The Geodetic Survey Division (GSD) of Natural Resources Canada (NRCan) has the primary role of maintaining, improving, and facilitating access to the Canadian Spatial Reference System (CSRS), which is the basis for a standard national reference system [25]. Free access to the CSRS Online Database is available through the GSD website [25], which allows the user to generate a listing of CSRS survey monuments filtered by one of several search criteria.

In this case, a search radius of 30 km around CYAZ, 49°4' 48.0" N 125°46' 12.0" W, and accepting any horizontal or vertical stations generates a list of 89 potential monuments. The "short" list provides a compact table of the potential stations that allows for one to create an initial ranking according to suitability. From the CYAZ proximity list, only 6 of the 89 stations report positions in tenths of a second (or better): 27727, 65H6203, 697963, 7073001, 867008, and 867010. Since station 27727 does not have any elevation data, it is not suitable.

The "long" list entries for the five suitable stations are extracted and examined for factors that further affect suitability. The most important aspect at this stage is accessibility. Station 867008 access is listed by helicopter, making it difficult, expensive and inconvenient to use. Station 697963 provides no information on access, adding an element of risk should it's use be requires. Another important aspect is the last inspection/publication date, which ranges from 1969 to 2002. Finally, the description of the monument may give clues as to the suitability of the station. Here, 65H6203 is described as having a damaged top with the centre point obliterated, which makes using the monument significantly less useful.

Taking into consideration all these factors, station 867010 (Figure D.1) appears to provide a substantially superior monument than is normally expected, and was used as the basestation site for the establishment of a virtual monument at CYAZ.

Figure D.1: *Survey monument 867010 at Radar Hill, near Tofino, BC.*

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Natural Resources Canada
Geodetic Survey Division
615 Booth Street, Ottawa, Ontario
Telephone: 613-995-4410
Fax: 613-995-3215
Internet: information@geod.nrcan.gc.ca

Horizontal Datum: NAD83CSRS
Vertical Datum: CGVD28
Note: Users of Geodetic Survey Division markers must obtain permission from the landowner before entering private property.

Selection Criteria: Radial Search

30.0 km 49 4 48.0 125 46 12.0 ( 49.079998 125.770004 )

Data Type Requested: Any Horizontal or Vertical stations (NAD83CSRS/CGVD28)

Number of Stations Retrieved: 89


        GEOLIST LEGEND:
        ---------------
 STN NO - STATION NUMBER
 NAME   - STATION NAME
 EAG    - ESTABLISHING AGENCY
 HDA    - HORIZONTAL VALUES AGENCY
 O      - HORIZONTAL ORDER OF ACCURACY (1st OCCURRENCE)
        - VERTICAL ORDER OF ACCURACY (2nd OCCURRENCE)
 M      - HORIZONTAL SURVEY METHOD (1st OCCURRENCE) *
        - VERTICAL SURVEY METHOD (2nd OCCURRENCE)
 YRA    - HORIZONTAL ADJUSTMENT YEAR(1st OCCURRENCE)
        - VERTICAL ADJUSTMENT YEAR (2nd OCCURRENCE)
```

I - INTEGRATION STATUS
VDA - VERTICAL VALUES AGENCY
Q - VERTICAL QUALITY FACTOR
D - VERTICAL DATUM
SMC - STATION MARKER CLASS
COND - SURVEY MARKER CONDITION

* Horizontal Method 'Y' indicates value available on another datum, not NAD83CSRS.

Definition of Reference Systems

NAD83CSRS: North American Datum 1983 Canadian Spatial Reference System. An adjustment of the Canadian Base Network and high order GPS tied to the Canadian Active Control System (CACS). Reference ellipsoid is GRS80. These coordinates may not be compatible with NAD83 public values.

NAD83: North American Datum 1983. (Public horizontal reference system). The horizontal control datum for the U.S., Canada, Mexico and Central America, based on the geocentric reference ellipsoid Geodetic Reference System 1980 (GRS80).

NAD27: North American Datum 1927. A non-geocentric horizontal control datum for the U.S., Canada and Mexico, defined by a coordinate and azimuth with origin at Meades Ranch, on the Clarke 1866 reference ellipsoid.

CGVD28: Canadian Geodetic Vertical Datum 1928, mean sea level. (Adopted, public vertical reference system.). The average height of the surface of the sea for all stages of the tide. Usually determined by averaging height readings observed hourly over a minimum period of 19 years.

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Values are NAD83CSRS

Controlling Agency: Geodetic Survey of Canada

Note: The accuracy of a horizontal or vertical value is indicated by its order, not by the number of decimal places printed. Horizontal method 'Y' indicates value available on another datum, not NAD83CSRS.

STN NO	NAME	EAG	Latitude	Longitude	HDA	O	I	M	YRA	ELEVATION	VDA	O	Q	M	DATUM	YRA	SMC	COND	NTS
27727	SHELTER IS	100	48 54 29.2	125 30 35.6				Y									1	1	092C13
58C9001	HS3-1958	100	49 9 14	125 54 30		S		S		1.930	100	1	P	1	CGVD28	2002	1	1	092F04
65H6203	2C3 RADAR	100	49 5 2.5	125 50 28.9				Y		125.418	100	1	P	1	CGVD28	2002	1	1	092F04
67C9000	HS6-1967	100	49 9 9	125 54 26		S		S		20.295	100	1	P	1	CGVD28	2002	1	1	092F04
697963	CORNER	100	48 59 31.2	125 35 9.6				Y		40.6	100	2	A	1	CGVD28	1969	3	1	092C13
69C9800	8595-4-1969	100	48 56 35	125 33 0		S		S		18.531	100	1	P	1	CGVD28	1990	1	1	092C13
7073001	TOFINO	100	49 9 14.8	125 54 35.0				Y		5.0	100	Y	P	8	CGVD28	1987	1	1	092F04
75C9800	8595-1-1975	100	48 56 46	125 33 1		S		S		2.253	100	1	P	1	CGVD28	2002	1	1	092C13
77C3024	9049-77	100	49 11 16	125 24 4		S		S		34.651	100	1	P	1	CGVD28	2002	1	1	092F03
77C3025	9050-77	100	49 6 59	125 26 12		S		S		97.190	100	1	P	1	CGVD28	2002	1	1	092F03
78C039	78C039	100	49 11 16	125 24 5		S		S		34.612	100	1	P	1	CGVD28	2002	1	1	092F03
78C040	78C040	100	49 10 43	125 23 38		S		S		33.068	100	1	P	1	CGVD28	2002	1	1	092F03
78C041	78C041	100	49 9 42	125 24 44		S		S		21.351	100	1	P	1	CGVD28	2002	1	1	092F03
78C042	78C042	100	49 9 5	125 25 11		S		S		16.392	100	1	P	1	CGVD28	2002	1	1	092F03
78C043	78C043	100	49 7 49	125 24 56		S		S		8.869	100	1	P	1	CGVD28	2002	1	1	092F03
78C044	78C044	100	49 7 16	125 25 33		S		S		40.390	100	1	P	1	CGVD28	2002	1	1	092F03
78C045	78C045	100	49 7 1	125 26 9		S		S		97.176	100	1	P	1	CGVD28	2002	1	1	092F03
78C046	78C046	100	49 6 52	125 26 19		S		S		69.233	100	1	P	1	CGVD28	2002	1	1	092F03
78C047	78C047	100	49 6 50	125 26 56		S		S		28.389	100	1	P	1	CGVD28	2002	1	1	092F03
78C048	78C048	100	49 6 26	125 27 18		S		S		30.992	100	1	P	1	CGVD28	2002	1	1	092F03
78C049	78C049	100	49 5 51	125 27 0		S		S		41.447	100	1	P	1	CGVD28	2002	1	1	092F03
78C050	78C050	100	49 5 19	125 27 20		S		S		40.057	100	1	P	1	CGVD28	2002	1	1	092F03
78C051	78C051	100	49 4 54	125 27 38		S		S		46.541	100	1	P	1	CGVD28	2002	1	1	092F03
78C052	78C052	100	49 4 28	125 28 3		S		S		52.531	100	1	P	1	CGVD28	2002	1	1	092F03
78C053	78C053	100	49 3 54	125 27 58		S		S		7.683	100	1	P	1	CGVD28	2002	1	1	092F03
78C054	78C054	100	49 3 13	125 28 44		S		S		25.783	100	1	P	1	CGVD28	2002	1	1	092F03
78C055	78C055	100	49 2 50	125 29 42		S		S		9.065	100	1	P	1	CGVD28	2002	1	1	092F03
78C056	78C056	100	49 2 23	125 31 30		S		S		10.969	100	1	P	1	CGVD28	2002	1	1	092F04
78C057	78C057	100	49 1 27	125 32 25		S		S		30.014	100	1	P	1	CGVD28	2002	1	1	092F04
78C058	78C058	100	49 0 55	125 34 3		S		S		41.479	100	1	P	1	CGVD28	2002	1	1	092F04
78C059	78C059	100	49 0 44	125 34 10		S		S		43.867	100	1	P	1	CGVD28	2002	1	1	092F04
78C060	78C060	100	48 59 51	125 34 44		S		S		37.552	100	1	P	1	CGVD28	2002	1	1	092C13
78C061	78C061	100	48 59 30	125 35 8		S		S		39.194	100	1	P	1	CGVD28	2002	1	1	092C13
78C062	78C062	100	48 58 49	125 34 53		S		S		35.751	100	1	P	1	CGVD28	2002	1	1	092C13

78C063	78C063	100	48	58	12	125	35	20		S		S		30.196	100	1	P	1	CGVD28	1990	1	1	092C13
78C064	78C064	100	48	57	25	125	34	48		S		S		47.325	100	1	P	1	CGVD28	1990	1	1	092C13
78C065	78C065	100	48	56	51	125	34	21		S		S		11.769	100	1	P	1	CGVD28	2002	1	1	092C13
78C066	78C066	100	48	56	45	125	33	2		S		S		1.519	100	1	P	1	CGVD28	2002	1	1	092C13
78C067	78C067	100	48	56	29	125	32	40		S		S		24.271	100	1	P	1	CGVD28	2002	1	1	092C13
78C068	78C068	100	48	56	21	125	32	32		S		S		26.473	100	1	P	1	CGVD28	2002	1	1	092C13
78C069	78C069	100	48	56	14	125	32	27		S		S		21.260	100	1	P	1	CGVD28	2002	1	1	092C13
78C070	78C070	100	48	59	25	125	35	8		S		S		40.837	100	1	P	1	CGVD28	2002	1	1	092C13
78C071	78C071	100	49	0	4	125	36	7		S		S		33.449	100	1	P	1	CGVD28	2002	1	1	092F04
78C072	78C072	100	49	0	44	125	37	24		S		S		24.273	100	1	P	1	CGVD28	2002	1	1	092F04
78C074	78C074	100	49	2	11	125	39	43		S		S		38.338	100	1	P	1	CGVD28	2002	1	1	092F04
78C075	78C075	100	49	2	33	125	40	56		S		S		39.147	100	1	P	1	CGVD28	2002	1	1	092F04
78C076	78C076	100	49	2	55	125	42	14		S		S		39.847	100	1	P	1	CGVD28	2002	1	1	092F04
78C077	78C077	100	49	3	46	125	43	35		S		S		34.144	100	1	P	1	CGVD28	2002	1	1	092F04
78C079	78C079	100	49	4	22	125	45	54		S		S		3.883	100	1	P	1	CGVD28	2002	1	1	092F04
78C080	78C080	100	49	4	40	125	47	12		S		S		20.301	100	1	P	1	CGVD28	2002	1	1	092F04
78C081	78C081	100	49	5	4	125	48	11		S		S		20.364	100	1	P	1	CGVD28	2002	1	1	092F04
78C082	78C082	100	49	5	29	125	49	50		S		S		17.695	100	1	P	1	CGVD28	2002	1	1	092F04
78C083	78C083	100	49	5	38	125	50	53		S		S		12.636	100	1	P	1	CGVD28	1990	1	1	092F04
78C084	78C084	100	49	6	7	125	51	44		S		S		4.959	100	1	P	1	CGVD28	2002	1	1	092F04
78C085	78C085	100	49	6	49	125	52	47		S		S		5.366	100	1	P	1	CGVD28	2002	1	1	092F04
78C086	78C086	100	49	7	48	125	53	53		S		S		7.653	100	1	P	1	CGVD28	1990	1	1	092F04
78C087	78C087	100	49	8	49	125	53	23		S		S		13.912	100	1	P	1	CGVD28	2002	1	1	092F04
78C088	78C088	100	49	9	11	125	54	0		S		S		14.533	100	1	P	1	CGVD28	1990	1	1	092F04
78C089	78C089	100	49	9	17	125	54	23		S		S		2.566	100	1	P	1	CGVD28	2002	1	1	092F04
78C090	78C090	100	49	9	0	125	54	13		S		S		29.358	100	1	P	1	CGVD28	2002	1	1	092F04
78C091	78C091	100	49	4	47	125	46	0		S		S		23.365	100	1	P	1	CGVD28	2002	1	1	092F04
81C3006	9201-81	100	49	9	15	125	54	29		S		S		2.423	100	1	P	1	CGVD28	2002	1	1	092F04
81C3007	9202-81	100	49	9	18	125	54	22		S		S		2.752	100	1	P	1	CGVD28	1986	1	1	092F04
81C3008	9203-81	100	49	8	59	125	54	19		S		S		29.566	100	1	P	1	CGVD28	2002	1	1	092F04
81C3009	9204-81	100	49	6	26	125	52	39		S		S		6.336	100	1	P	1	CGVD28	2002	1	1	092F04
867008	FREDY	100	48	59	6.5	125	30	24.7				Y		737.9	100	Y	P	2	CGVD28	1991	1	1	092C13
867010	867010	100	49	5	2.5959	125	50	28.6892	100	Y	A	R	2001	125.266	100	1	P	1	CGVD28	2002	1	1	092F04
86C006	86C006	100	48	55	21	125	32	19		S		S		20.623	100	1	P	1	CGVD28	2002	1	1	092C13
86C3001	9051-86	100	48	55	16	125	32	24		S		S		20.704	100	1	P	1	CGVD28	1986	1	1	092C13

90C3003	AGS-SCREW	100	48	55	18	125	32	22		S		S		16.599	100	1	P	1	CGVD28	2002	1	1	092C13
90C3004	GRAV STA	100	48	55	20	125	32	26		S		S		20.529	100	1	P	1	CGVD28	2002	1	1	092C13
90C501	90C501	100	48	56	22.2845	125	32	44.2374	100	Y	A	R	2001	28.568	100	1	P	1	CGVD28	2002	1	1	092C13
90C502	AMPHITRITE	100	48	55	32.3006	125	32	29.7213	100	Y	A	R	2001	27.900	100	1	P	1	CGVD28	2002	1	1	092C13
90C503	90C503	100	48	55	21	125	32	20		S		S		16.603	100	1	P	1	CGVD28	2002	1	1	092C13
90C504	90C504	100	49	9	16	125	54	23		S		S		9.821	100	1	P	1	CGVD28	2002	1	1	092F04
947001	UCLU WCDA-ACP	103	48	55	32.2793	125	32	29.8460	100	Y	A	R	2002	28.569	100	1	P	1	CGVD28	2002	1	1	092C13
947001B	UCLU REF B	100	48	55	32	125	32	28		S		S									1	1	092C13
967002	WICKANINNISH	100	49	0	41	125	40	31		S		S									1	1	092F04
97C9106	97C9106	106	49	9	13.3618	125	54	14.4487	100	Y	A	R	2000	14.9	100	Y	X	Z	CGVD28	2001	Y	1	092F04
9874001	RS1 R302	192	48	55	27.6739	125	32	32.0123	100	Y	A	R	2002								1	1	092C13
9874002	RS2 R303	192	48	55	28.3122	125	32	30.9814	100	Y	A	R	2002								1	1	092C13
9874003	IM1 I302	192	48	55	28.3274	125	32	31.0771	100	Y	A	R	2002								1	1	092C13
9874004	IM2 I303	192	48	55	27.7312	125	32	32.0585	100	Y	A	R	2002								1	1	092C13
M027008	M027008	100	49	7	2	125	26	14		S		S		112.101	100	1	P	1	CGVD28	2002	1	1	092F03
M027009	M027009	100	49	1	2	125	33	19		S		S		62.007	100	1	P	1	CGVD28	2002	1	1	092F04
M027029	9957-2002	100	49	11	13	125	24	7		S		S		34.645	100	1	P	1	CGVD28	2002	1	1	092F03
M027033	9955-2002	100	49	9	16	125	54	29		S		S		2.763	100	1	P	1	CGVD28	2002	1	1	092F04
M027034	9956-2002	100	49	5	3	125	50	28		S		S		124.845	100	1	P	1	CGVD28	2002	1	1	092F04
M02C003	M02C003	100	48	57	26	125	34	50		S		S		53.659	100	1	P	1	CGVD28	2002	1	1	092C13

Number of Stations Retrieved: 89

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****

SITE IDENTIFICATION

Unique Number : 65H6203
Name : 2C3 RADAR
Established By : B.C. Ministry Of Environment (Surveys And Mapping Branch)
Province : BC
Prov. Identifier : 65H6203
NTS Map No : 092F04

STATION COORDINATES

Horizontal Datum : NAD83
Method : Values should be checked with provincial agency
Latitude : N49 05' 02.51745
Longitude : W125 50' 28.90393
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : NMIP93
UTM :   Zone = 10   N = 5440686.130 m   E =   292537.454 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation :   125.418 m
Order : First Order
Method : Differential
Adjustment Line : N1C02
Published Year : 2002
Inspected in : 2002
Status : Good
Inspection Comments : No inspection text on file

Accessible by passenger car or light truck and a walk of less than 50 m

TOFINO

RADAR HILL LOOKOUT, 1.4 KM SOUTHWEST OF JUNCTION WITH HIGHWAY NO. 4, TABLET IN TOP OF LARGE ROCK OUTCROP, 18.6 M WEST OF CENTRE OF STEPS TO TELESCOPE, 3.9 M EAST OF CENTRE AXIS OF TELESCOPE, 8 M ABOVE PARKING LOT LEVEL. ESTABLISHED BY B.C. SURVEYS AND MAPPING BRANCH AND STAMPED "6203", WITH A DAMAGED TOP AND OBLITERATED CENTRE POINT. STATION IS REF POINT TO STATION 867010 "RADAR GEOID".

REFERENCE STATIONS INFORMATION:

Reference name, Marker type, AZ/DIR/BRNG (DEG MIN SEC), (H)orizontal or (S)loped distance (m), and Diff. in elev. (cm)

867010	(AZ)	BRASS/BRONZE TABLET OR CAP	56 56' 24	H	4.88	-15

HISTORICAL COORDINATES   NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Multiple Methods
Latitude : N49 05' 02.51745
Longitude : W125 50' 28.90393
UTM : Zone = 10 N = 5440686.130 m E = 292537.454 m

Horizontal Datum : NAD27
Method : Electronic Traversing
Latitude : N49 05' 03.24100
Longitude : W125 50' 23.74400
UTM : Zone = 10 N = 5440485.660 m E = 292636.261 m

PROJECTS IDENTIFIERS:
49125 CP90213 VA2C73 CAARE69 CP86218 JUNE90
PA4925A VA_ADJ

Station 5 of 89

****

SITE IDENTIFICATION

Unique Number : 697963
Name : CORNER
Established By : Geodetic Survey Division - Nrcan
Province : BC
Prov. Identifier : None
NTS Map No : 092C13

STATION COORDINATES

Method : Scaled
Latitude : N48 59' 31
Longitude : W125 35' 10
Agency : Geodetic Survey Division - NRCan
UTM : Zone = 10 N = 5429789 m E = 310832 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation : 40.6 m
Order : Second Order
Method : Differential
Adjustment Line : NOVA1969
Published Year : 1969

STATION MARKER INFORMATION AND LOCATION

Marker Type : Station Evidence
Inspected in : 1969
Status : Good
Inspection Comments : None

HISTORICAL COORDINATES NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD27
Method : Electronic Traversing
Latitude : N48 59' 31.79600
Longitude : W125 35' 10.94700
UTM : Zone = 10 N = 5429589.355 m E = 310799.185 m

PROJECTS IDENTIFIERS:
CAARE69

Station 7 of 89

****

SITE IDENTIFICATION

Unique Number : 7073001
Name : TOFINO
Established By : B.C. Ministry Of Lands, Parks And Housing (Legal Surveys Bra
Province : BC
Prov. Identifier : None
NTS Map No : 092F04

STATION COORDINATES

Horizontal Datum : NAD83
Method : Values should be checked with provincial agency
Latitude : N49 09' 14.79027
Longitude : W125 54' 34.98525
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : NMIP93
UTM : Zone = 10 N = 5448664.273 m E = 287846.353 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation : 5.0 m
Order : Consult Agency (Unique Condition)
Method : Global Positioning System
Adjustment Line : NOVA1987
Published Year : 1987
Inspected in : 1987
Status : Good
Inspection Comments : None

Accessible by passenger car or light truck and a walk of less than 50 m

MKR TYPED SETTING CODE 02

LOC AT THE PUBLIC WHARF IN THE TOWN OF TOFINO, ON VANCOUVER ISLAND AT THE TERMINUS OF CAMPBELL AVE. MKD BY A BR TAB SET FLUSH IN THE CONC BASE OF A METAL SIGN "TOFINO B.C. PACIFIC TERMINUS TRANS-CANADA HIGHWAY". STA IS 4 M W OF A HYDRO POLE AND LIGHT DTANDARD. THE TAB IS A BRITISH COLUMBIA LEGAL SURVEY MRK STPD "1970 18 51 WT 10 N 322" THE CONC BASE IS BEHIND THE BASE OF A LOG BENCH.

HISTORICAL COORDINATES   NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Global Positioning System
Latitude : N49 09' 14.79027
Longitude : W125 54' 34.98525
UTM :   Zone = 10   N = 5448664.273 m   E =   287846.353 m

PROJECTS IDENTIFIERS:
GPS   PRIM_HORI

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****

SITE IDENTIFICATION

Unique Number : 867008
Name : FREDY
Established By : Geodetic Survey Division - Nrcan
Province : BC
Prov. Identifier : None
NTS Map No : 092C13

STATION COORDINATES

Horizontal Datum : NAD83
Method : Values should be checked with provincial agency
Latitude : N48 59' 06.49977
Longitude : W125 30' 24.71453
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : NMIP93
UTM :   Zone = 10   N = 5428832.050 m   E =   316595.067 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation :   737.9 m
Order : Consult Agency (Unique Condition)
Method : Simultaneous Trig Levels
Adjustment Line : NOVA1991
Published Year : 1991
Inspected in : 1996
Status : Good
Inspection Comments : No inspection text on file

Accessible by helicopter and a walk of less than 50 m

MKR TYPE D SETTING CODE 06

LOC ABOUT 8 M E OF HIGH POINT OF ROCK RUBBLE ON SUMMIT OF MOUNT FREDERICK. IMMEDIATE AREA IS ROCK RUBBLE ABOVE BEDROCK. RUBBLE IS FROM EXPLOSIVES USED TO CLEAR OVERBURDEN. REF "A" AND "B" ARE COUNTERSUNK INTO FRACTURED BEDROCK. MKD BY A GSC BR TAB SET IN BEDROCK.

REFERENCE STATIONS INFORMATION:

Reference name, Marker type, AZ/DIR/BRNG (DEG MIN SEC), (H)orizontal or (S)loped distance (m), and Diff. in elev. (cm)

```
     BLACK (AZ)       BRASS/BRONZE TABLET OR CAP   69 51' 27
    867008A (AZ)      BRASS/BRONZE TABLET OR CAP   96 26' 25     H     1.86     -19
    867008B (AZ)      BRASS/BRONZE TABLET OR CAP   189 01' 57     H     2.27      2
  867008A TO  867008B       0 00' 00     S     3
```

HISTORICAL COORDINATES   NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Multiple Methods
Latitude : N48 59' 06.49977
Longitude : W125 30' 24.71453
UTM : Zone = 10   N = 5428832.050 m   E = 316595.067 m

PROJECTS IDENTIFIERS:
GPS   JUNE90   PRIM_HORI

Station 67 of 89

****

SITE IDENTIFICATION

Unique Number : 867010
Name : 867010
Established By : Geodetic Survey Division - Nrcan
Province : BC
Prov. Identifier : None
NTS Map No : 092F04

STATION COORDINATES

Horizontal Datum : NAD83CSRS
Method : Global Positioning System
Latitude : N49 05' 02.5959   +/- 0.002 m
Longitude : W125 50' 28.6892   +/- 0.001 m
Ellipsoidal Height : 107.41 m   +/- 0.008 m
Geoid Separation (HTv2.0) : -17.862 m
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : M01709
Epoch : 1997
UTM : Zone = 10   N = 5440688.39 m   E = 292541.90 m
XYZ Coords.: =   X = -2450755.20 m   Y = -3392898.00 m   Z = 4796767.40 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation : 125.266 m
Order : First Order

Method : Differential
Adjustment Line : N1C02
Published Year : 2002

STATION MARKER INFORMATION AND LOCATION

Marker Type : Permanent Agency Marker
Inspected in : 2002
Status : Good
Inspection Comments : No inspection text on file

Accessible by passenger car or light truck and a walk of 50 to 500 m

TOFINO

RADAR HILL LOOKOUT, 1.4 KM SOUTHWEST OF JUNCTION WITH HIGHWAY NO. 4, TABLET IN TOP OF LARGE ROCK OUTCROP, 13.7 M WEST OF CENTRE OF STEPS TO TELESCOPE, 8.8 M EAST OF CENTRE AXIS OF TELESCOPE, 8 M ABOVE PARKING LOT LEVEL. TRIANGULATION STATION "RADAR".

REFERENCE STATIONS INFORMATION:

Reference name, Marker type, AZ/DIR/BRNG (DEG MIN SEC), (H)orizontal or (S)loped distance (m), and Diff. in elev. (cm)

657137 (AZ)	BRASS/BRONZE TABLET OR CAP	236 56' 24	H	4.88	15
867008 (AZ)	BRASS/BRONZE TABLET OR CAP	114 05' 38			

HISTORICAL COORDINATES NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Multiple Methods
Latitude : N49 05' 02.59444
Longitude : W125 50' 28.69009
UTM : Zone = 10 N = 5440688.345 m E = 292541.880 m

PROJECTS IDENTIFIERS:
49125 CP90213 VA2C73 CP86218 GPS JUNCTION JUNE90
VA_ADJ PRIM_HORI

Annex E
Autumn Climate for Tofino

Table E.1: *Climate data for autumn months in Tofino, BC [26]. Codes indicate the amount of data available to determine the time-averages.*

- A: No more than 3 consecutive or 5 total missing years between 1971 to 2000.
- B: At least 25 years of record between 1971 and 2000.
- C: At least 20 years of record between 1971 and 2000.
- D: At least 15 years of record between 1971 and 2000.

Temperature:	Sep	Oct	Nov	Code
Daily Average (°C)	13.3	9.8	6.6	A
Standard Deviation	1.0	0.9	1.5	A
Daily Maximum (°C)	17.7	13.5	9.8	A
Daily Minimum (°C)	8.9	6.0	3.3	A
Extreme Maximum (°C)	29.4	23.9	21.1	
Date (yyyy/dd)	1963/09	1945/07+	1970/03	
Extreme Minimum (°C)	-0.6	-3.5	-12.7	
Date (yyyy/dd)	1972/27	1984/31	1985/29	
Precipitation:				
Rainfall (mm)	133.5	340.2	471.2	A
Snowfall (cm)	0.0	0.0	3.4	A
Precipitation (mm)	133.5	340.2	474.9	A
Average Snow Depth (cm)	0	0	0	C
Median Snow Depth (cm)	0	0	0	C
Snow Depth at Month-end (cm)	0	0	0	A
Extreme Daily Rainfall (mm)	105.9	154.2	155.4	
Date (yyyy/dd)	1968/16	1967/07	1975/12	
Extreme Daily Snowfall (cm)	0.0	1.2	22.6	
Date (yyyy/dd)	1942/01+	1984/31	1973/03	
Extreme Daily Precipitation (mm)	105.9	154.2	155.4	
Date (yyyy/dd)	1968/16	1967/07	1975/12	
Extreme Snow Depth (cm)	0.0	0.0	13.0	
Date (yyyy/dd)	1959/01+	1959/01+	1975/30	
Days with Maximum Temperature:				
≤ 0 °C	0.0	0.0	0.14	A
> 0 °C	30.0	31.0	29.9	A
> 10 °C	30.0	28.8	14.2	A
> 20 °C	6.1	0.52	0.0	A
> 30 °C	0.0	0.0	0.0	A
> 35 °C	0.0	0.0	0.0	A
Days with Minimum Temperature:				

> 0 °C	30.0	29.9	23.3	A
≤ 2 °C	0.21	4.0	10.6	A
≤ 0 °C	0.03	1.1	6.7	A
< -2 °C	0.0	0.17	2.3	A
< -10 °C	0.0	0.0	0.03	A
< -20 °C	0.0	0.0	0.0	A
< -30 °C	0.0	0.0	0.0	A
Days with Rainfall:				
≥ 0.2 mm	12.2	18.4	22.1	A
≥ 5 mm	5.6	12.9	16.8	A
≥ 10 mm	4.2	9.8	13.9	A
≥ 25 mm	1.7	4.9	7.3	A
Days With Snowfall:				
≥ 0.2 cm	0.0	0.03	0.86	A
≥ 5 cm	0.0	0.0	0.21	A
≥ 10 cm	0.0	0.0	0.07	A
≥ 25 cm	0.0	0.0	0.0	A
Days with Precipitation:				
≥ 0.2 mm	12.2	18.4	22.5	A
≥ 5 mm	5.6	12.9	17.0	A
≥ 10 mm	4.2	9.8	13.9	A
≥ 25 mm	1.7	4.9	7.4	A
Days with Snow Depth:				
≥ 1 cm	0.0	0.0	0.29	C
≥ 5 cm	0.0	0.0	0.21	C
≥ 10	0.0	0.0	0.08	C
≥ 20	0.0	0.0	0.0	C
Wind:				
Maximum Hourly Speed	80.0	77.0	100.0	
Date (yyyy/dd)	1962/28	1962/12+	1962/29	
Direction of Maximum Hourly Speed	SE	SE	SE	
Maximum Gust Speed	113.0	113.0	117.0	
Date (yyyy/dd)	1962/28	1962/12	1962/29	
Direction of Maximum Gust	SE	SE	SE	
Degree Days:				

Above 24 °C	0.0	0.0	0.0	A
Above 18 °C	0.3	0.0	0.0	A
Above 15 °C	7.9	0.1	0.0	A
Above 10 °C	100.4	24.9	3.6	A
Above 5 °C	248.5	148.3	63.8	A
Above 0 °C	398.5	302.4	198.5	A
Below 0 °C	0.0	0.0	1.5	A
Below 5 °C	0.0	0.9	16.7	A
Below 10 °C	1.8	32.6	106.5	A
Below 15 °C	59.3	162.7	252.9	A
Below 18 °C	141.7	255.7	342.9	A
Bright Sunshine:				
Total Hours	174.6	118.3	62.5	A
Days with measurable	25.7	21.9	17.2	A
% of possible daylight hours	46.1	35.3	22.6	A
Extreme Daily	12.6	10.3	8.6	A
Date (yyyy/dd)	1975/12	1972/03	1973/01	
Humidex:				
Extreme Humidex	33.6	25.9	20.6	
Date (yyyy/dd)	1963/09	1991/10	1970/03	
Wind Chill:				
Extreme Wind Chill	-2.6	-5.9	-13.6	
Date (yyyy/dd)	1972/27	1984/31	1985/23	
Humidity:				
Average Relative Humidity - 0600LST (%)	95.5	95.0	91.8	D
Average Relative Humidity - 1500LST (%)	72.9	78.3	81.6	A

Annex F
Cal Site Trial Logs

During flight operations, details of events at the calibration site were logged, including radio communications, telephone calls, weather, and observed changes to targets of opportunity that might be imaged in passes over the Cal Site. The daily logs are provided in Tables F.1–F.8. Most locations refereed to in the Tables correspond to those identified in Figure F.1.

Table F.1: *Cal Site observations for 21 September, Day "B".*

GPS Time (PDT)	Observations
	CSA collection; Cal Site in last line only
08:40	TFB basestation powered on
08:48	TFA basestation powered on
11:50	Noah/Eurocom discovered stuck in reboot, not responding to keyboard, hard shutdown enacted
11:59	Eurocom rebooted
12:01	Radio check, no response; testing Noah susceptibility to RF sources, not triggered
12:02	Radio check, no response; Noah not triggered
12:03	Radio check, no response; Noah not triggered
12:45	Rain showers ended, low cloud
12:48	White 3-ton truck with yellow box arrives along Airport Road and departs
13:02	Brown 1/2-ton truck (crew cab) drives NW along T/W F to Shed; Sedan arrives along Airport Road and enters Main Gate to N of Maintenance Building
13:03	1/2-ton truck returns to Maintenance SE along T/W F
13:07	Green Altima departs fenceline Centre Gate along Airport Road
13:10	1/2-ton truck departs through Main Gate along Airport Road
13:15	A/C overflies CYAZ at altitude, N to S
13:16	Radio: RSC on line, 6 min out
13:17	Light A/C lands E along R/W 10 28
13:22	Spitting rain begins
13:23	Radio: Cal Site acquired; request 30 min run for GPS basestations
13:26	Altima returns along Airport Road to fenceline Centre Gate

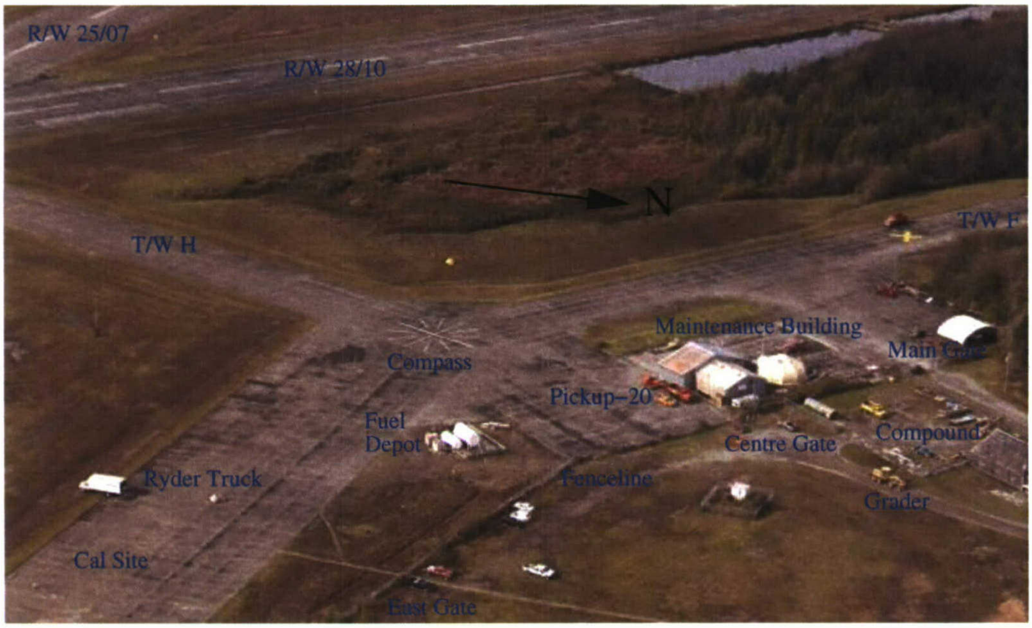

Figure F.1: *Locations around Cal Site referred to by daily logs.*

Table F.2: *Cal Site observations for 23 September, Day "C".*

GPS Time (PDT)	Observations
07:54	TFB basestation powered on
08:04	TFA basestation powered on
08:30	Noah startup shows high noise background
08:50	Significant water discovered in Noah electronics box
08:52	Noah shutdown, box disconnected
08:54	Pickup-20 departs E along T/W G
08:57	Noah box opened: 3/16" of water flooding covering some components; $> 1l$ water poured out
09:00	Phone: flight delayed, awaiting clearance, ETD 09:30
09:02	Phone: CCG informed of flight delay
09:18	Phone: RSC cleared for T/O
09:20	Phone: CCG informed of flight status; Pickup-20 returns to Maintenance Building
09:31	Road grader arrives along Airport Road
09:32	Pickup-20 moves to end of T/W F facing NW
09:34	Green hatchback travels NW along T/W F and turns right
09:35	Grader departs along Airport Road
09:36	White F-350 travels E along fenceline to East Gate
09:41	Pickup-20 travels NW along T/W F and turns left

09:44	Green hatchback returns SE along T/W F to Main Gate
09:50	Black SUV arrives along Airport Road and enters Compound
09:52	Hydro cherry-picker arrives along Airport Road to Weather Station
09:53	Red 1/2-ton truck (crew cab) departs along Airport Road from Compound
09:56	Black SUV departs along Airport Road from Compound; White sedan arrives along Airport Road and departs
09:59	TFA discovered not recording, F10 not pushed, recording started 17:00:33 UTC
10:00	Radio: RSC has started southbound line 2 min earlier; partly cloudy; TFAC started
10:04	Radio: Start image L1P1
10:08	Cherry-picker departs along Airport Road
10:11	White 1/2-ton arrives along Airport Road and departs
10:16	Grader returns along Airport Road
10:17	Radio: Start image L1P2
10:22	Radio: End image L1P2
10:24	Radio: RSC departing for Nanoose Bay; break until noon return
11:51	CP-140 circles CYAZ; Radio: Demon-03 call sign
12:08	Radio: Demon-03 and RSC establish contact
12:10	Radio: RSC announces 1 minute to line start; high cloud
12:11	Radio: Start image L1P8
12:20	Pickup-20 moves to end of T/W F facing NW
12:21	Black truck arrives through Main Gate
12:22	The two trucks travel NW on T/W F
12:24	Radio: End image L1P8
12:38	Radio: Start image L1P9
12:39	Wine SUV arrives along Airport Road
12:40	SUV departs along Airport Road
12:41	SUV returns along Airport Road to fenceline Centre Gate
12:48	SUV departs fenceline Centre Gate along Airport Road
12:50	Green hatchback travels NW along T/W F; Radio: End image L1P9
12:51	Light A/C lands W on R/W 25/07
12:52	Green hatchback returns SE along T/W F to Main Gate
12:59	Red 1/2-ton truck (crew cab) arrives along Airport Road to Compound
13:03	Red 1/2-ton departs along Airport Road from Compound
13:05	Radio: 30 s, 2 nm from start of image L1P10; Budget cube van arrives along Airport Road to Compound
13:06	Car departs along Airport Road from Compound
13:07	Budget cube van departs along Airport Road from Compound
13:10	Blue 3-ton truck (wood box) departs along Airport Road from Compound
13:14	Pickup-20 and black truck return SE on T/W F to Maintenance Building

13:20	Float plane heading S overflies to W of CYAZ; Black truck departs along Airport Road from Maintenance Building; Second black truck departs along Airport Road from Compound
13:22	Sea King arrives from E
13:23	Radio: End image L1P10
13:24	Sea King circles, lands R/W 25/07 and T/W H
13:25	Sea King taxis NE along T/W H to Fuel Depot
13:27	Float plane heading S overflies to W of CYAZ; Silver sedan arrives along airport Road
13:29	Sea King engines disengaged
13:30	Sea King rotors stopped
13:33	Radio: Start image L1P11
13:34	Grey minivan arrives along Airport Road
13:37	White sedan moves to end of Airport Road; Minivan travels to Main Gate
13:39	Minivan departs along Airport Road
13:50	Sea King rotors restarted
13:52	Radio: Start image L1P12
13:53	Small plane taxis from E along R/W 25/07 then NE along T/W H, pulls off toward Maintenance Building
13:55	Sea King departs Fuel Depot SW along T/W H up to R/W 25/07 and holds
13:57	Sea King moves onto R/W 25/07
13:58	Sea King lifts off and travels W over R/W 25/07
14:01	Silver sedan departs along Airport Road
14:02	Green Altima moves next to Maintenance Building
14:05	Radio: Start image L1P13
14:09	Pickup-20 moves to end of T/W F facing NW
14:15	Pickup-20 travels NW along T/W F
14:16	Radio: End image L1P13; RSC departs for CYQQ; 30 min run for GPS basestations

Table F.3: *Cal Site observations for 24 September, Day "D".*

GPS Time (PDT)	Observations
09:00	Phone: MTI cancels flight due to CCG job action
09:15	Phone: Proposed switch of Sep 24 and Sep 25 planned activities
09:25	TFB basestation powered on
09:42	TFA basestation powered on
10:00	Phone: Confirmation that Sep 25 PolSAR acquisitions to be advanced to Sep 24; estimate wheels up at 11:00
11:16	Coast Guard H/C arrives from SE to Fuel Depot; rotors shut-down

11:27	Phone: RSC tire problem delays wheels-up until 11:45
11:41	H/C rotors spin up
11:43	H/C departs to W from Fuel Depot
11:48	Green Altima moves from fenceline Centre Gate
11:55	Radio: RSC reports 10 minutes until Start of L1P1
12:09	Radio: Lead-in to L1P1
12:13	Radio: Start image L1P1
12:31	Radio: End of L1P1; no image recorded, radar failed
12:32	Small A/C lands on R/W 25/07 heading W
12:48	Radio: End of test line; Cal Site not observed; no signal detected by Noah
12:49	Red 1/2-ton truck (crew cab) arrives along Airport Road to Compound
12:50	Industrial mower arrives along Airport Road to Compound
12:51	Silver sedan arrives along Airport Road to Main Gate; Red 1/2-ton truck departs along Airport Road from Compound
12:52	Sedan moves from Main Gate to fenceline Centre Gate
12:56	Radio: Lead-in to L1P2
13:01	Radio: Start image L1P2
13:02	Noah: signal detected
13:08	Light A/C lands on R/W 25/07 heading W
13:15	Silver sedan departs along Airport Road from fenceline Centre gate; White 3-ton truck (flatbed) departs along Airport Road
13:17	Radio: End of image L1P2
13:23	Radio: Start image L1P3
13:30	A/C taxis E on R/W 25/07 to end of R/W
13:35	A/C take-off to W on R/W 25/07; Radio: End image L1P3, Cal Site observed
13:42	Radio: Lead-in to L1P4
13:47	Radio: Start image L1P4; Noah: signal detected
13:49	A/C taxis E on R/W 25/07 to end of R/W
13:50	Second A/C overflies CYAZ E to W
13:51	A/C take-off to W on R/W 25/07
13:53	Second A/C lands on R/W 25/07 heading W
14:02	Radio: End image L1P4
14:07	Radio: Lead-in to L1P5
14:16	CCG A/C lands on R/W 25/07 heading W
14:18	CCG A/C taxis E on R/W 25/07 to T/W H, NE on T/W H to Fuel Depot; Radio: End image L1P5; CCG A/C engine shut-down
14:26	Radio: Lead-in to L1P6
14:31	Radio: Start image L1P6
14:32	Noah: signal detected
14:36	Radio: Cal Site observed
14:37	Radio: Re-broadcast Cal Site observed

14:38	Radio: Re-broadcast Cal Site observed; Cal-Site radio attached to external antenna allows acknowledgment broadcast to be heard by RSC
14:47	Radio: End image L1P6
14:53	CCG A/C right engine start
14:54	Radio: Lead-in to L1P7
14:55	CCG A/C left engine start
15:56	CCG A/C taxis SW along T/W H from Fuel Depot to R/W 25/07
14:57	CCG A/C take-off on R/W 25/07 heading W
15:02	Radio: End of L1P7
15:15	Backhoe departs along Airport Road from Compound
15:17	Radio: Lead-in to L2P8
15:18	Dump truck departs along Airport Road from Compound
15:21	Radio: RSC reports 20 nm past start of L2P8
15:24	RSC visually spotted to NE of Cal Site
15:25	H/C EH-101 overflies R/W 25/07 heading W
15:27	EH-101 turns NE over CYAZ
15:35	Radio: End of L2P8; RSC departs for CYQQ; request GPS basestations to run until 16:00

Table F.4: *Cal Site observations for 25 September, Day "E".*

GPS Time (PDT)	Observations
	MMTI collection, Cal Site in last two lines only
09:07	TFB basestation powered on
09:18	TFA basestation powered on
10:28	Start image L1P1; Low fog, mostly sunny
12:12	Battery alarm sounds on GPS basestation TFA, TFA down
12:18	Radio: Lead-in for L7P7 over MMTI vessel
12:20	Radio: RSC check with Cal Site; response not heard with hand-held; switched to whip antenna, comms resolved
12:27	Radio: End image L7P7
12:30	Battery alarm sounds on GPS basestation TFB
12:32	Rental truck battery extracted for back-up to basestations
12:34	Radio: Lead-in for L8P8 over MMTI vessel
12:43	TFB basestation down, restarted
12:44	Radio: End of L8P8
12:48	Radio: Lead-in for L9P9 over Cal Site; Thick fog, visibility 150 m
12:55	Radio: At centre of L9P9
12:56	Radio: ARC observed; TFB basestation taken down for battery switch
12:58	Radio: End of L9P9; TFB restarted
13:02	Radio: RSC beginning racetrack
13:15	Radio: Lead-in for L9P10 over Cal Site

13:19	Radio: Start image L9P10
13:22	Radio: Cal Site observed
13:25	Radio: End of L9P10; RSC departs for CYQQ; GPS to run until 14:00
14:00	TFB shut-done; battery returned to rental truck

Table F.5: *Cal Site observations for 27 September, Day "F".*

GPS Time (PDT)	Observations
	MMTI collection, Cal Site in last two lines only
09:18	TFB powered on
09:25	TFA powered on
12:05	ARCs powered up
13:00	Radio: RSC reports L8P9 transit line already ended and heading for Cal Site
13:11	Radio: Lead-in for L9P10 over Cal Site; Sunny and clear
13:13	Radio: Start of image L9P10
13:15	RSC spotted visually to NE
13:16	Noah: signal detected
13:17	Black coupe arrives along Airport Road and departs
13:19	White 1/2-ton truck (with box) arrives along Airport Road to Compound
13:21	Small A/C lands on R/W 25/07 heading W
13:30	Second A/C takes-off from R/W 25/07 heading E
13:33	Radio: Lead-in to L10P11 over Cal Site
13:39	Radio: Cal Site observed; End of L10P11; RSC departs for CYQQ
14:12	GPS basestations shut down

Table F.6: *Cal Site observations for 28 September, Day "G".*

GPS Time (PDT)	Observations
	GMTI collection, Cal Site in one or two passes
09:23	TFB basestation powered on
09:28	TFA basestation powered on
11:07	Radio: RSC check with Cal Site, difficulty reaching GSP
12:54	Radio: End of L6P6 over controlled vehicles; Next pass over Cal Site
12:56	A/C engine start at Maintenance Building
12:57	A/C taxis onto T/W H Compass
13:00	H/C overflies CYAZ from N, circles, lands at Fuel Depot
13:03	Radio: Lead-in for L7P7 over Cal Site, only calibration pass, if good
13:05	H/C engines shut down

13:06	Bobcat moving at NW end of T/W F
13:08	Radio: Centre of L7P7, looking for ARC
13:16	Radio: End of L7P7, confirm Cal Site observed and no second pass over Cal Site, return to MMTI collection
14:32	Radio: RSC expected CYQQ landing at 14:50, GPS to run until 14:50
14:33	Radio: End of last pass
14:50	GPS basestations shut down

Table F.7: *Cal Site observations for 29 September, Day "H".*

GPS Time (PDT)	Observations
	CSA collection, Cal Site in one pass only
09:24	TFB basestation powered on
09:29	TFA basestation powered on
12:35	Radio: RSC check, ETA 13:00
12:39	Radio: RSC updates ETA to 13:30
13:17	Yellow A/C taxis SE along T/W F to Maintenance Building
13:18	White minivan departs along Airport Road
13:33	Twin engine A/C overflies CYAZ from S to N; White sedan travels along Apron III from Global Express to Ryder Truck to Maintenance Building; Small A/C lands on R/W 25/07 heading W
13:36	Dump truck arrives along Airport Road through Main Gate and NW along T/W F
13:42	Radio: ARCs observed, GPS to run until 14:30
13:44	White sedan travels from Maintenance Building to Global Express
13:59	Radio: RSC reports delay to landing, GPS to run until 15:00
15:00	GPS basestations shut down

Table F.8: *Cal Site observations for 30 September, Day "I".*

GPS Time (PDT)	Observations
	CSA collection, Cal Site in one pass only
11:22	TFA basestation powered on
11:52	TFB basestation powered on
15:59	Radio: RSC check, 15-20 minutes to calibration pass
15:42	Small A/C taxis along R/W 25/07 heading E to wend of R/W
15:44	Flatbed truck carrying Hi-Hoe enters through Main Gate and stops; A/C takes off on R/W 25/07 heading W
15:46	Truck arrives along Airport Road through Main gate, then NW along T/W F and left at end

15:48	Flatbed travels NW on T/W F from Main Gate
15:55	Phone: from RSC reporting change in planned Line to heading 133° T, left look inland; no changes to Cal Site required
15:57	Radio: Lead-in to pass over Cal Site, 3 minutes to image start
16:00	Radio: Start image pass
16:03	Radio: Cal Site observed, end of pass, GPS to run until 16:33
16:04	A/C starts props at fenceline East Gate
16:05	A/C taxis SW along T/W H from fenceline East Gate
16:28	Battery alarm sounds on TFA basestation
16:30	TFA basestation shut down
16:48	TFB basestation shut down

Annex G
Ground Truth for CCGC Cape St. James

DRDC deployed pitch/roll sensors to record selected marine and land targets angular movements during the CoCoNaut trial, the systems coming from BMT Fleet Technology.

One such system was deployed onboard the *Cape St. James* for the 23 September PolSAR collection, providing Date/Time, Pitch and Roll in degrees collected at 1 Hz.

The system is a FAS-G inclinometer made by MicroStrain Inc. [1] (Figure G.1), combining an angular rate gyro with two orthogonal DC accelerometers, a multiplexer, and a microcontroller to provide an analog voltage linearly proportional to inclination in dynamic and static environments. This sensor operates over the full 360° range of angular motion. Positive pitch indicates bow up, positive roll indicates starboard side up [12].

In addition to the pitch/roll sensor, a Trimble GPS receiver was used to record the position and linear motion of the vessel, which is plotted in Figure K.1. A description of the vessel specifications is given in Table G.1.

Figure G.1: *MicroStrain FAS-G inclinometer [1].*

Table G.1: Data Sheet for CCGC Cape St. James *[27].*

Vessel Name:	CCGC Cape St. James
Vessel Type:	Multi-Task High Endurance Lifeboat
Call Sign:	CF 7633
Home Port:	Tofino, BC
Port of Registry:	Ottawa
Official Number:	821250
Built:	1999 — MIL/Metal Craft Marine, Kingston Ontario
Description:	High speed self-righting MLB, Home Trade Class II vessel with sea keeping ability to sea state 5.
Duties:	Search & Rescue, Fisheries Patrol and Enforcement, Pollution Response, and other tasks as required.
Crewing:	Staffed from 0800hrs to 1600hrs 7 days a week with the crew on call by pager for 16 hours.
Registered Tonnage:	Gross: 33.79 (996.93 m^3) Net: 25.35 (717.63 m^3) Displacement: 19.955 metric tonnes (approx.)
Length:	14.63 m (48 ft)
Breadth:	4.7 m (14 ft)
Draft:	1.37 m (4.5 ft)
Crew:	Crew of 4
Accommodations:	5 spare berths for survivors
Communication Equipment:	1 HF/1 VHF-GMDSS/2 VHF/1 VHF AM/MSAT/AUTL
Navigation Equipment:	2 GMDSS/1 RADAR/1 ELECTRONIC CHART SYSTEM
Propulsion:	2 × Caterpillar 3196 geared diesel engines with two fixed-pitch, four blade propellers.
Horsepower:	671 kW (900 HP)
Max. Speed:	25 knots (46.3 kph / 28.8 mph)
Cruising Speed:	22 knots (40.7 kph / 25.3 mph)
Fuel Capacity:	1450 litres (318.96 imp gals.)
Water Capacity:	22.7 litres (4.84 Imp gals.)
Electrical:	2 engine-driven 120V AC generators, 5kW each; 2 shaft-driven 24V DC generators, 280 Amp each
Cleared Deck Space:	Fore 26m^2 Aft 57m^2
Towing Capability:	2 nylon braid. 150 tons displacement
Auxiliary Equipment:	1 Zodiac G380 with Auto Inflation & 15 H.P. Outboard

Annex H
Targets of Opportunity in Nanoose Bay

In addition to the lines flown off the west coast of Vancouver Island, on 23 September 2004, there were five other lines flown over targets of opportunity in the Nanoose Bay area off the east coast of Vancouver Island. The time and location of those lines is shown in Table H.1. The quick look polarimetric images are shown in Figure H.1. Note that the winds were extremely light during these acquisitions. A few of the lines appear to show changes in the radar gain. Although the lines are correlated with gain changes, they are a secondary effect associated with a corresponding change in the rate of analogue-to-digital converter (ADC) saturation, which leads to an image power loss. The actual gain change is compensated for in the processor and would not be visible in the processed image if not for the ADC saturation power loss.

Table H.1: *Summary of additional lines flown on 23 September 2004.*

Date	Tstart	Tstop	Line	Pass	Look	Corners
23 Sept 2004	17:38:23	17:44:19	5	3	R	N49.360582 W124.426349 N49.361176 W123.732579 N49.187624 W124.423671 N49.188212 W123.733521
23 Sept 2004	17:51:20	17:56:25	6	4	L	N49.458469 W123.792985 N49.321411 W124.360014 N49.305783 W123.658881 N49.320980 W124.585082
23 Sept 2004	18:08:52	18:13:48	7	5	L	N49.231795 W124.362527 N49.232304 W123.785035 N49.408052 W124.365232 N49.408503 W123.784010
23 Sept 2004	18:22:15	18:27:42	8	6	R	N49.148395 W123.800867 N49.324850 W124.268926 N49.300773 W123.665493 N49.477655 W124.134495
23 Sept 2004	18:36:57	18:42:29	5	7	R	N49.300767 W124.275251 N49.299838 W123.628282 N49.127396 W124.228505 N49.123755 W123.630058

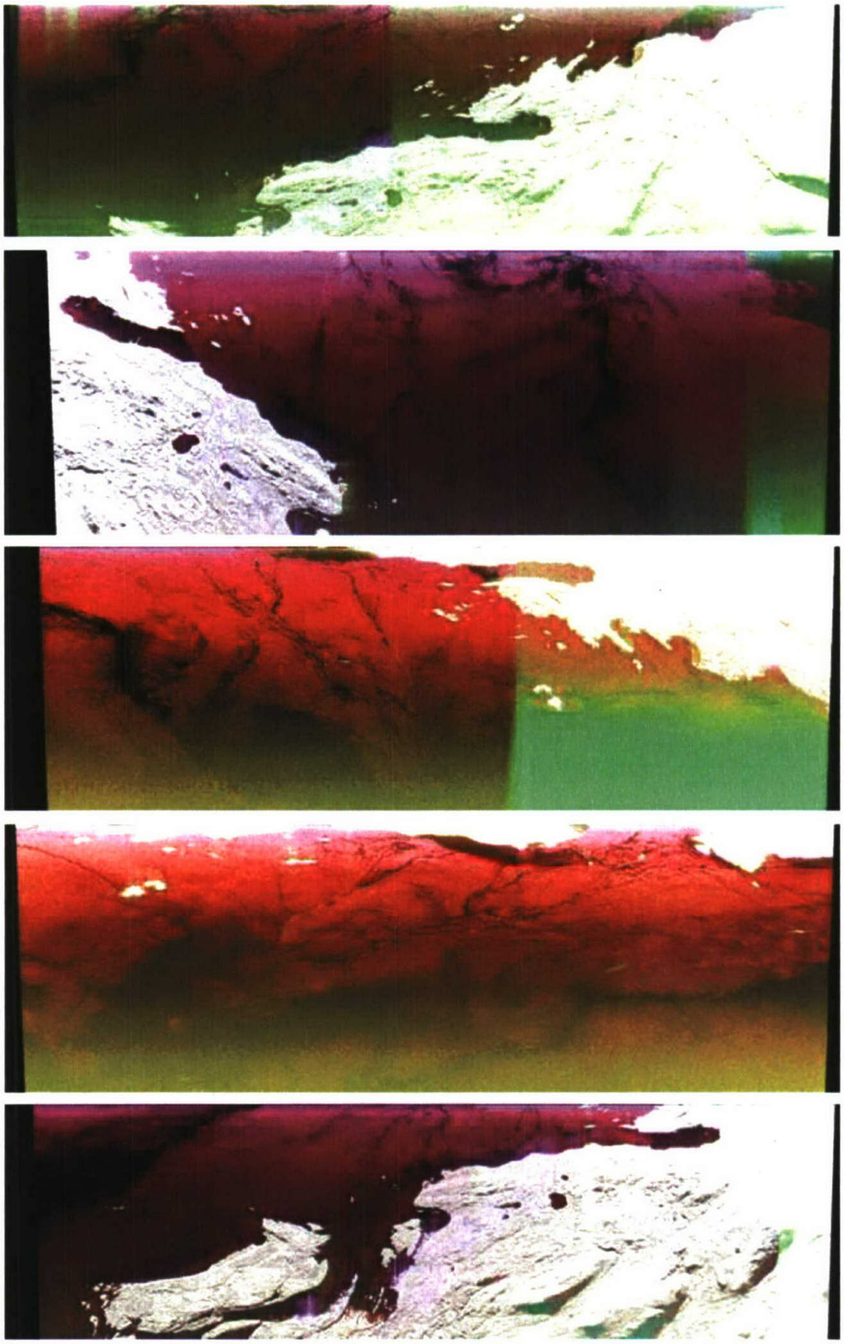

Figure H.1: *Nanoose Bay imagery from 23 September. The polarimetric channels are represented by colour: Red=$|VV|$; Blue=$|HH|$; Green=$|HV|+|VH|$. From top to bottom: Line 5 Pass 3, Line 6 Pass 4, Line 7 Pass 5, Line 8 Pass 6, and Line 5 Pass 7.*

Annex I
Communications Plan

I.1 Broadcast Communications

a. The EC Convair 580 SAR played the lead role in the experiment. All other vessels or aircraft were cued by the Convair and supported its work. Frequencies for vessel and aircraft communications were:

   (a) Primary Communications
   - 30 Minutes Prior to C-GRSC Departure
     - HF 25,100 upper S/B
   - During Operations
     - CV 580, vessels — Channel 19 — 161.55
     - CP 140, CV 580's — 1223 VHF
     - CV 580's Cal Site — 149.59 FM
   - Alternate Communication
     - CP 140, CV 580's — 123.45 VHF, 2237 HF U/SB, UHF — 249.8

   (b) Secondary Communications
   - HF — 2237 U/SB — All participants
   - VHF — 126.7 — All participants where applicable.

b. Secondary communication were only to be used if directed by C-GRSC.

c. Emergency Frequencies were VHF — 121.0, VHF/FM — 156.8, HF — 2182.

d. C-GRSC attempted HF Communication with participants on HF 2510, 30 minutes prior to scheduled departure time, for each mission. All participants were asked to monitor HF 2510 upper S/B 30 minutes prior to scheduled departure for C-GRSC until exercise was called complete.

e. Call Signs:

   (a) EC CV-580, C-GRSC: Romeo Sierra Charlie
   (b) Provincial Airlines King Air Maritime Patrol Aircraft: Speedair 01
   (c) West Coast Wild, FPML: Foxtrot Poppa Mike Lima
   (d) CP-140 Aurora, 407 Sqn: Demon 03

I.2 Cal Site Radios

a. Air-ground communications at the calibration site were sought from Industry Canada via DTSES 5-3. Approval was received for the use of 148.090 MHz (Ground/Ground) and 151.295 MHz (Air/Ground/Air) for the period of the trial. The handheld radios in use were Motorola HT750's [28]. Detailed specifications (available frequency bands, power etc.) are available from Motorola [29].

I.3 Cell phones

a. GSM cell phones were requested from the 76 Communications Group Loaner Pool, for Cal Site and GMTI personnel. Unfortunately, these phones were reallocated to DND Strike Management Team, when collective bargaining fell apart. As a result of this late change and difficulties with arrangements, the rental cell phones obtained via 76 Comm Grp, through the vendour "Hello Anywhere", had to be shipped to the Cal Site personnel at their hotel in Tofino. A number of phones were also shipped to DRDC Ottawa and distributed to the GMTI team members, who participated in the trial and operated in the Comox/Nanoose Bay area.

b. Although voicemail was procured as part of the contract, no instructions were provided to enable the functionality. Some difficulty occurred in establishing contact to personnel the west side of the island, despite employing the analog capability. It has been suggested Telus (being the local provider to the area) could have provided phones with better reception.

c. As part of the communications plan, a contact list was distributed to the participants and DND players.

Annex J
Commercial Satellite Imagery Acquired

Commercial satellite imagery was also acquired during CoCoNaut, specifically four SAR images (two RADARSAT-1 images and two ENVISAT ASAR AP mode images), as listed in Table I.1. Unfortunately, the timing of the passes rendered these data unsuitable for ship location mapping due to the acquisition time differences between the satellite scenes, the CV-580 flight times, and the available ship validation data. Overviews of the four scenes are included here for completeness.

Table I.1. *Commercial satellite SAR imagery acquired for CoCoNaut.*

SENSOR	MODE	DATE, TIME (UTC)	REMARKS	FIGURE
ENVISAT ASAR	AP (HH/VV) IS5	23 Sept 2004, 06:13	11 hours prior to first CV-580 pass	J.1
ENVISAT ASAR	AP (HH/VV) IS4	2 Oct 2004, 18:38	8 days after last CV-580 pass	J.2
RADARSAT-1	SCNA	22 Sept 2004, 14:34	15 hours prior to first CV-580 pass	J.3
RADARSAT-1	S1	25 Sept 2004, 14:46	16 hours after last CV-580 pass	J.4

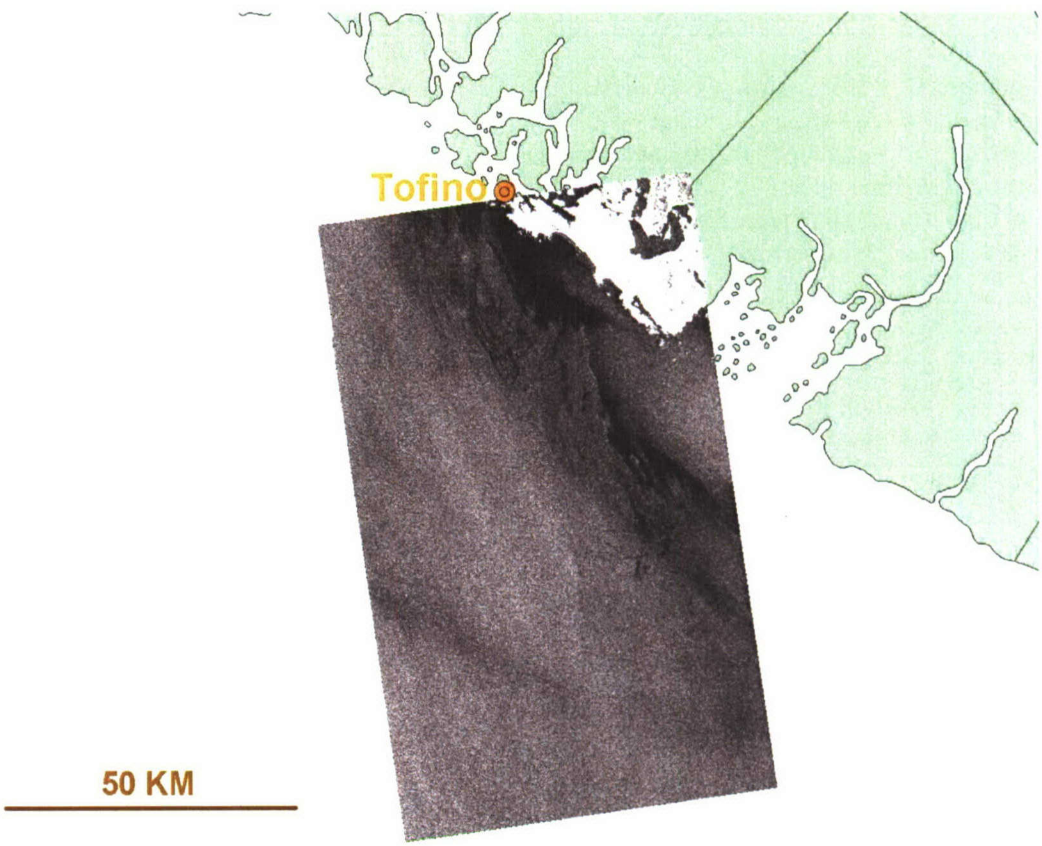

Figure J.1. *ENVISAT ASAR AP (HH Channel shown) IS5, 23 Sept. 2004, 06:13 UTC.*

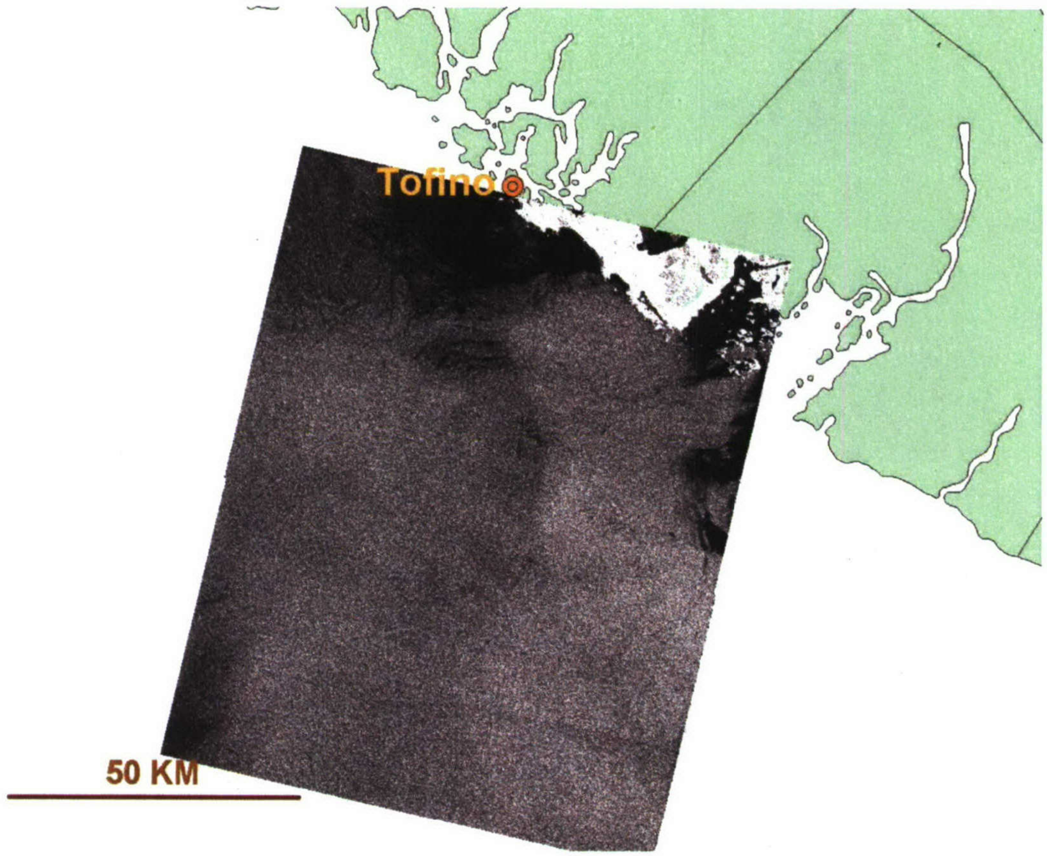

Figure J.2. *ENVISAT ASAR AP (HH Channel shown) IS4, 2 Oct. 2004, 18:38 UTC.*

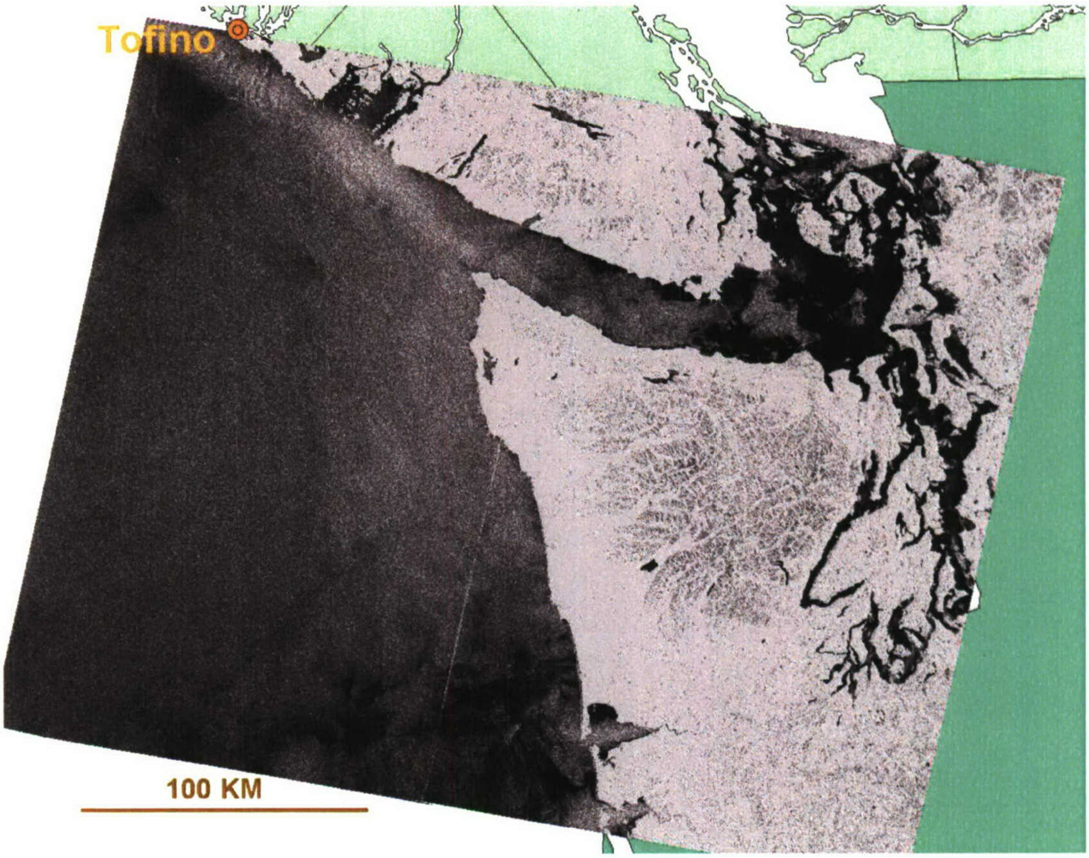

Figure J.3. *RADARSAT-1 SCNA, 22 Sept. 2004, 14:34 UTC.*

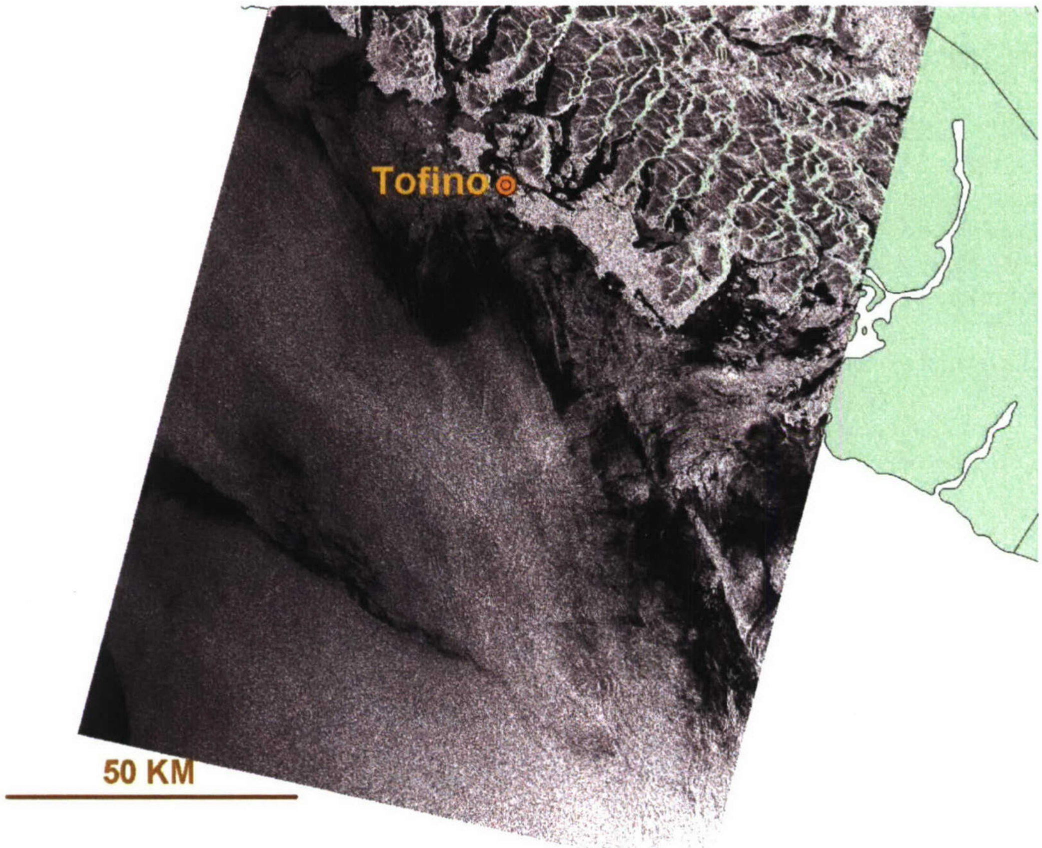

Figure J.4. *RADARSAT-1 S1, 25 Sept. 2004, 14:46 UTC.*

Annex K
Potential CV-580 SAR Contacts

On 23 and 24 Sept. 2004, the Environment Canada CV-580 airborne SAR acquired polarimetric SAR data over the Pacific Ocean off Tofino, British Columbia, Canada. Vantage Point International (VPI) was retained to analyze several concurrently acquired data sets to identify possible vessel contacts of opportunity that spatially and temporally coincided with the CV-580 SAR acquisition coverage area and acquisition times. This Annex was derived from the Vantage Point International project report.

The available data sets for correlation include:

- Hand held aerial photographic missions by DRDC Ottawa (J. Lange) on a West Coast Wild Adventures aircraft on both Sept. 23 and 24;
- A hand held aerial photographic mission by the Department of Fisheries and Oceans carried out by Provincial Airlines Ltd. on Sept. 24;
- Vessel position tracks from the Marine Communications and Traffic Service based upon the radar site at Mt. Ozzard on both Sept. 23 and 24; and
- A Canadian Coast Guard vessel track (CCGC *Cape St. James*) acquired on Sept. 23.

All of the data sets required preparation and reformatting before they were imported into ArcView Geographic Information System (GIS) for interpretation. Photographic data sets where reviewed and any multiple ship target images or non-ship images were removed. A script file that uses the freeware exifTool library was used to extract the camera latitude and longitude co-ordinates from the image header file. A table was created and imported into ArcView to create a point file. Vessel track data sets from both MCTS and CCG required reformatting of the co-ordinates to decimal degrees and negative longitude before being imported into and displayed in ArcView.

CV-580 flight tracks for Sept. 23 and 24 were created from aircraft GPS log files exported to text files and edited for required latitude/longitude format before being imported into ArcView. The flight lines were based on the flight log, helical scan recorder on time, and the off time minus 1 minute to account for noise calibration data recording that is routinely carried out at the end of each pass.

CV-580 SAR surface coverage polygons were derived from slant range calculations for the near, mid, and far slant range positions, which were then converted to ground range distance from the flight line. Polygons based on these offsets and the flight line lengths were then created. The basic geometry is given by:

$$R_{near} = (RGD - 13.3) \times 150$$
$$R_{mid} = R_{near} + 2047 \times 4$$
$$R_{far} = R_{near} + 4095 \times 4$$

where all ranges are in metres, the Range Gate Delay is in micro-seconds, and the slant range sample spacing is 4 metres.

The slant range values where converted to ground range using a flat Earth approximation:

$$R_G = \sqrt{R^2 - h^2}$$

where h is the platform altitude in metres.

Selection of ship targets that may be present in the CV-580 SAR imagery involved both temporal and spatial filtering of the photographic and ship track data sets. For each date a merged polygon of all of the CV-580 SAR coverage polygons was created and used to spatially "clip" the areas that fall under the CV-580 SAR geographic coverage. Temporal filtering of the photographic and ship track data sets was done based on the CV-580 flight line start and stop times. For the photographic data sets, targets were further refined by identifying stationary buoys, fish farms, and stationary vessel targets.

The output from this work follows below as set of tables and maps corresponding to each CV-580 flight line that show the potential vessel contacts that fit both the temporal and geographic requirements. The table is cross referenced to airborne photographs of the particular vessel contact. The photographs are marked in terms of their source (WCWA or DFO) and the photograph reference number. The results for 23 Sept. 2004 precede those of 24 Sept. 2004. For some cases on 24 Sept. 2004 photographs are available for from both sources. The cross-referenced figure number (WCWA to DFO and vice versa) can be read from the tables or appear in the figure caption.

Table K.1. *CV-580 Flight Lines and Times, 23 Sept. 2004.*

Line / Pass	Start Time (UTC)	Stop Time (UTC)
L1 / P1	17:02:32	17:07:15
L1 / P2	17:15:55	17:20:59
L1 / P8	19:14:08	19:27:13
L1 / P9	19:37:47	19:48:54
L1 / P10	20:03:25	20:20:16
L1 / P11	20:31:00	20:39:45
L1 / P12	20:50:50	20:57:33

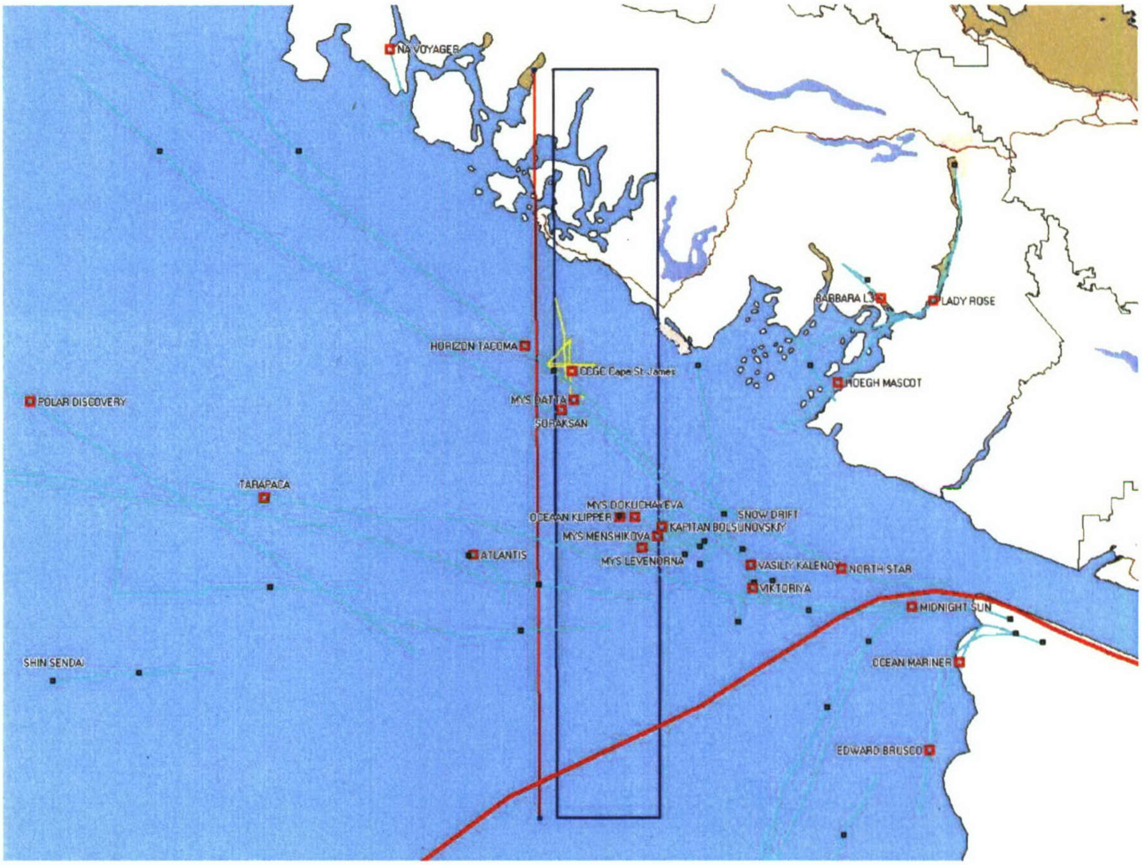

Figure K.1. *Map illustrating the CV-580 SAR acquisition scenario for 23 Sept. 2004: the nominal SAR coverage swath (dark blue box) is shown east of the aircraft nadir (red line); MCTS vessel tracks (cyan) include the vessel name and position (red box) at the start of the first flight line and the position (black square) at the end of the final flight line; CCGC Cape St. James track (yellow) was acquired with GPS.*

Table K.2. 23 Sept. 2004, Line 1 Pass 1.

On time (UTC)	17:02:32			
Off time (UTC)	17:06:15			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Mys Datta	17:03:00	48.835	-125.820	
Soraksan	17:03:00	48.817	-125.853	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
House Boat+Tug	20:22:30	49.127	-125.832	K.20

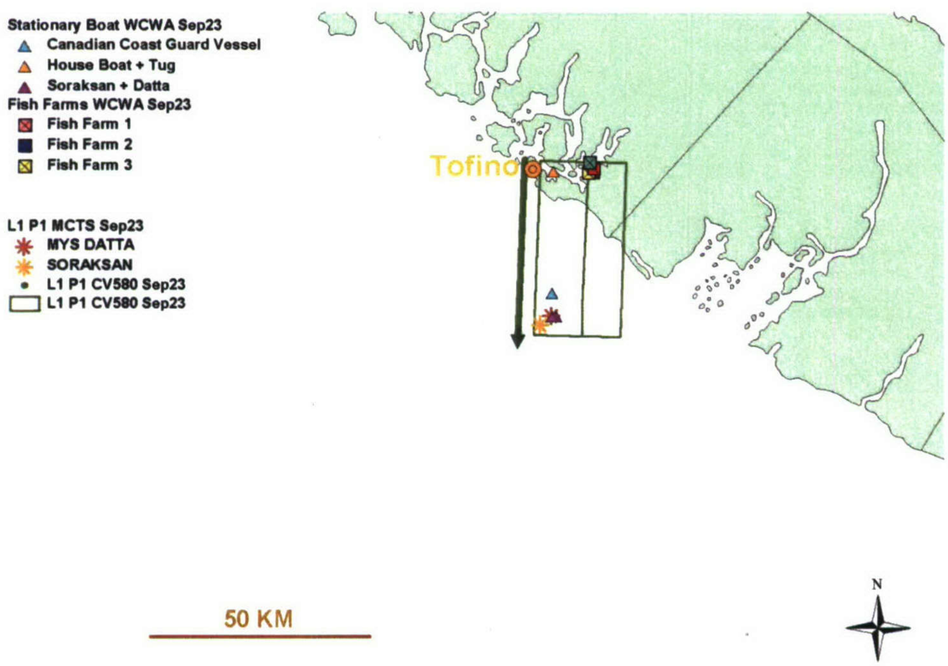

Figure K.2. 23 Sept. 2004, Line 1 Pass 1.

Table K.3. *23 Sept 2004, Line 1 Pass 2.*

On time (UTC)	17:15:55			
Off time (UTC)	17:19:59			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	17:15:00	48.817	-125.853	
Mys Datta	17:21:00	48.835	-125.818	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
House Boat+Tug	20:22:30	49.127	-125.832	K.20

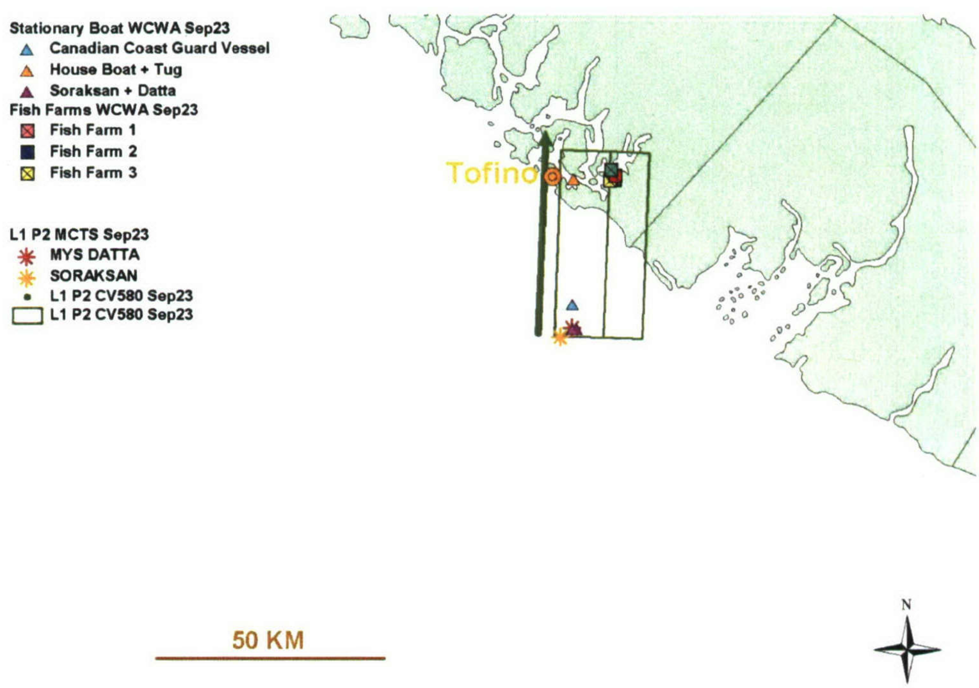

Figure K.3. *23 Sept. 2004, Line 1 Pass 2.*

Table K.4. *23 Sept. 2004, Line 1 Pass 8.*

On time (UTC)	19:14:08			
Off time (UTC)	19:26:13			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Oceaan Klipper	19:24:00	48.632	48.632	
Soraksan	19:24:00	48.835	48.835	
Tarapaca	19:24:00	48.565	48.565	
	CCG Time UTC	**CCG Lat**	**CCG Long**	
CCGC Cape St. James	19:14:36	48.88	-125.8	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
Oceaan Klipper	19:25:34	48.627	-125.685	K.15
Tsunami Sea	19:27:00	48.590	-125.679	K.16
Tarapaca	19:28:09	48.563	-125.697	K.17
House Boat+Tug	20:22:30	49.127	-125.832	K.20

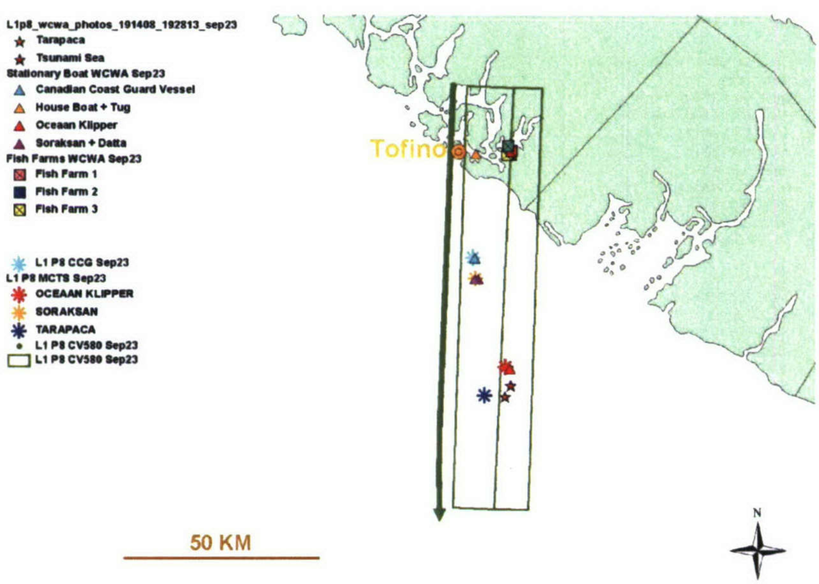

Figure K.4. *23 Sept. 2004, Line 1 Pass 8.*

Table K.5. *23 Sept. 2004, Line 1 Pass 9.*

On time (UTC)	19:37:47			
Off time (UTC)	19:47:54			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Oceaan Klipper	19:41:00	48.632	-125.698	
Soraksan	19:41:00	48.835	-125.817	
Tarapaca	19:41:00	48.543	-125.655	
	CCG Time UTC	**CCG Lat**	**CCG Long**	
CCGC Cape St. James	19:44:54	48.88	-125.82	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
Oceaan Klipper	19:25:34	48.627	-125.685	K.15
Tarapaca	19:28:09	48.563	-125.697	K.17
House Boat+Tug	20:22:30	49.127	-125.832	K.20

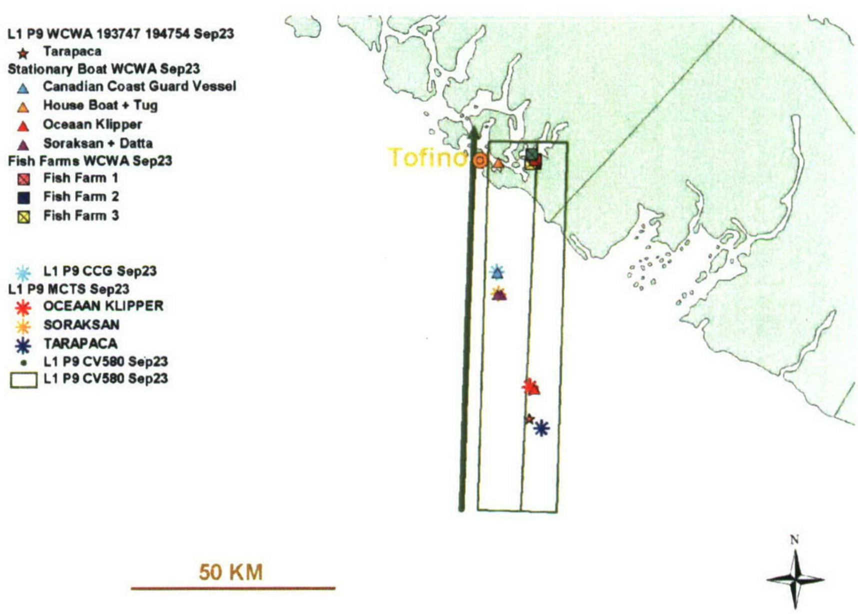

Figure K.5. *23 Sept. 2004, Line 1 Pass 9.*

Table K.6. *23 Sept. 2004, Line 1 Pass 10.*

On time (UTC)	20:03:25			
Off time (UTC)	20:21:16			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Oceaan Klipper	20:19:00	48.632	-125.698	
Soraksan	20:19:00	48.835	-125.817	
	CCG Time UTC	**CCG Lat**	**CCG Long**	
CCGC Cape St. James	20:10:16	48.88	-125.83	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+ Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
Oceaan Klipper	19:25:34	48.627	-125.685	K.15
Sail Boat 1	20:17:59	49.026	-125.836	K.18
Sail Boat 2	20:18:35	49.038	-125.831	K.19
House Boat+Tug	20:22:30	49.127	-125.832	K.20

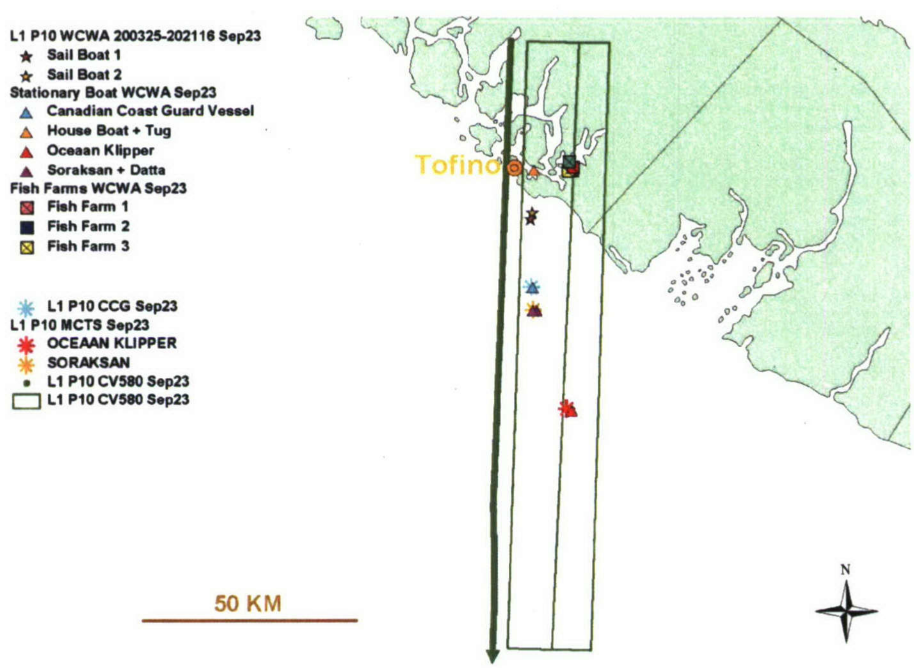

Figure K.6. *23 Sept. 2004, Line 1 Pass 10.*

Table K.7. 23 Sept. 2004, Line 1 Pass 11.

On time (UTC)	20:31:00			
Off time (UTC)	20:38:45			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Oceaan Klipper	20:35:00	48.632	-125.698	
Soraksan	20:35:00	48.835	-125.817	
	CCG Time UTC	**CCG Lat**	**CCG Long**	
CCGC Cape St. James	20:29:12	48.86	-125.83	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
CCGC Cape St. James	16:33:04	48.881	-125.823	K.14
Oceaan Klipper	19:25:34	48.627	-125.685	K.15
House Boat+Tug	20:22:30	49.127	-125.832	K.20

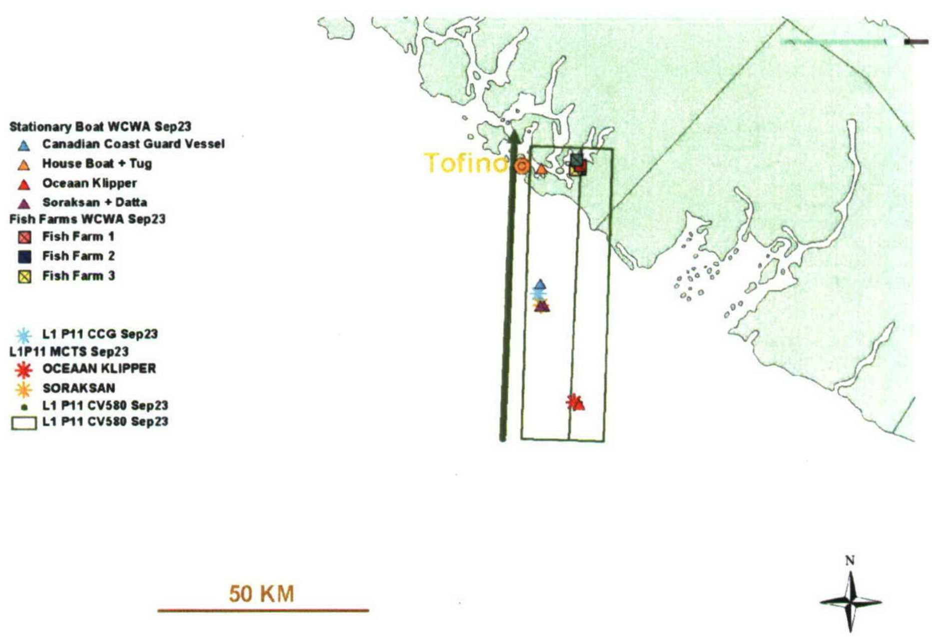

Figure K.7. 23 Sept. 2004, Line 1 Pass 11.

Table K.8. *23 Sept. 2004, Line 1 Pass 12.*

On time (UTC)	20:50:50			
Off time (UTC)	20:57:33			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	20:56:00	48.835	-125.817	
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Fish Farm 1	16:07:40	49.128	-125.709	K.9
Fish Farm 2	16:08:42	49.129	-125.722	K.10
Fish Farm 3	16:08:48	49.126	-125.723	K.11
Soraksan+Datta	16:23:19	48.833	-125.809	K.12
Soraksan+Datta	16:23:45	48.833	-125.821	K.13
House Boat+Tug	20:22:30	49.127	-125.832	K.20

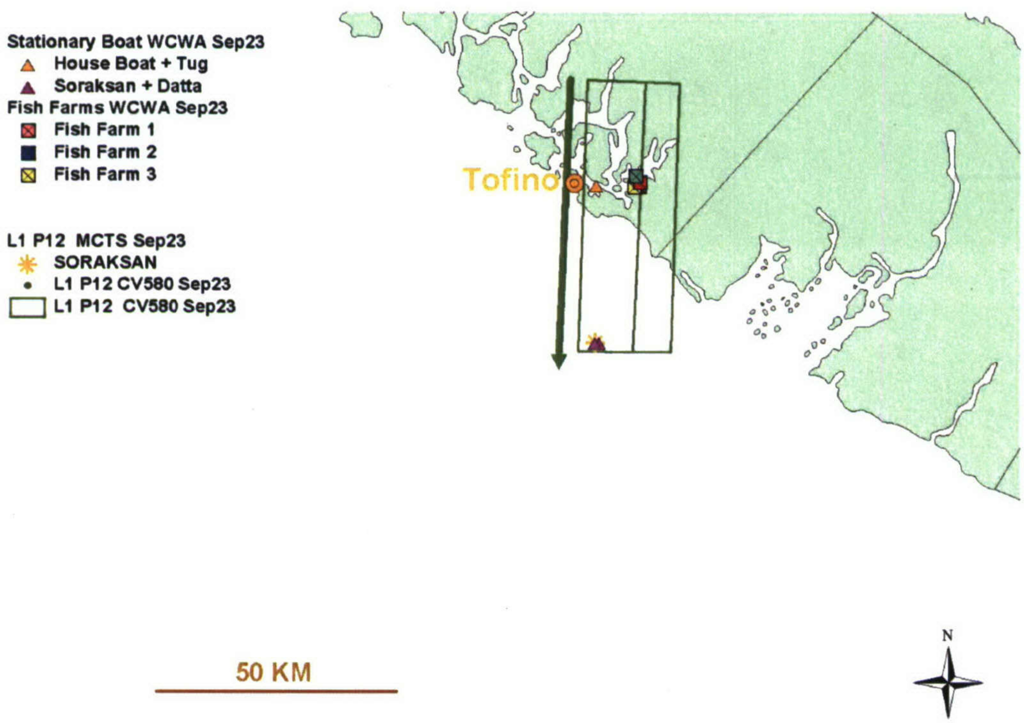

Figure K.8. *23 Sept. 2004, Line 1 Pass 12.*

Figure K.9. *WCWA, Fish Farm 1.*

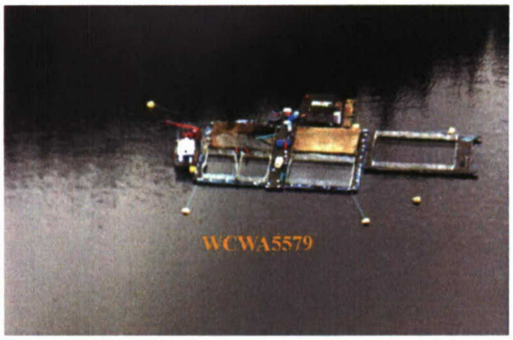

Figure K.10. *WCWA, Fish Farm 2.*

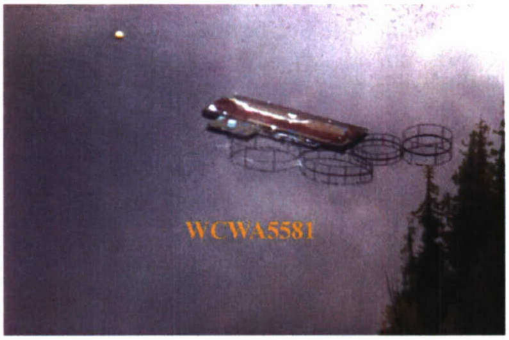

Figure K.11. *WCWA, Fish Farm 3.*

Figure K.12. *WCWA, Soraksan+Datta.*

Figure K.13. *WCWA, Soraksan+Datta.*

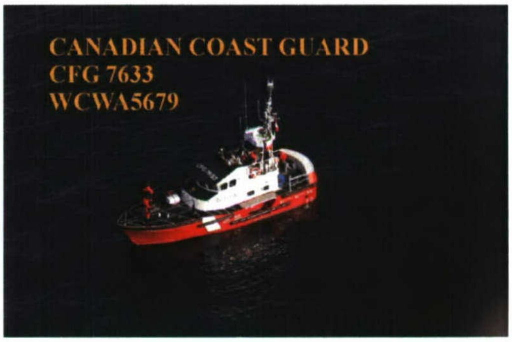

Figure K.14. *WCWA, CCGC Cape St. James.*

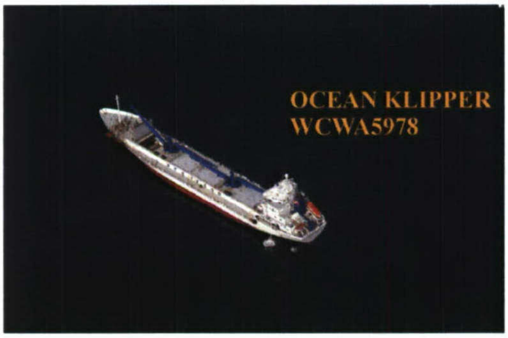

Figure K.15. *WCWA, Oceaan Klipper.*

Figure K.16. *WCWA, Tsunami Sea.*

Figure K.17. *WCWA, Tarapaca.*

Figure K.18. *WCWA, Sail Boat 1.*

Figure K.19. *WCWA, Sail Boat 2.*

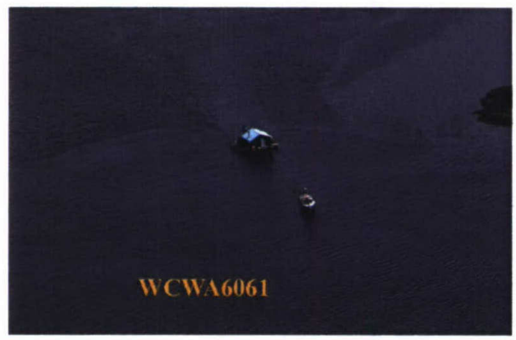

Figure K.20. *WCWA, House Boat+Tug.*

Table K.9. *CV-580 Flight Lines and Times, 24 Sept. 2004.*

Line / Pass	Start Time (UTC)	Stop Time (UTC)
L1 / P2	19:59:34	20:16:40
L1 / P3	20:23:38	20:34:17
L1 / P4	20:45:51	21:00:28
L1 / P5	21:09:26	21:18:55
L1 / P6	21:30:18	21:43:54
L1 / P7	21:53:40	22:02:50
L2 / P8	22:19:33	22:33:56

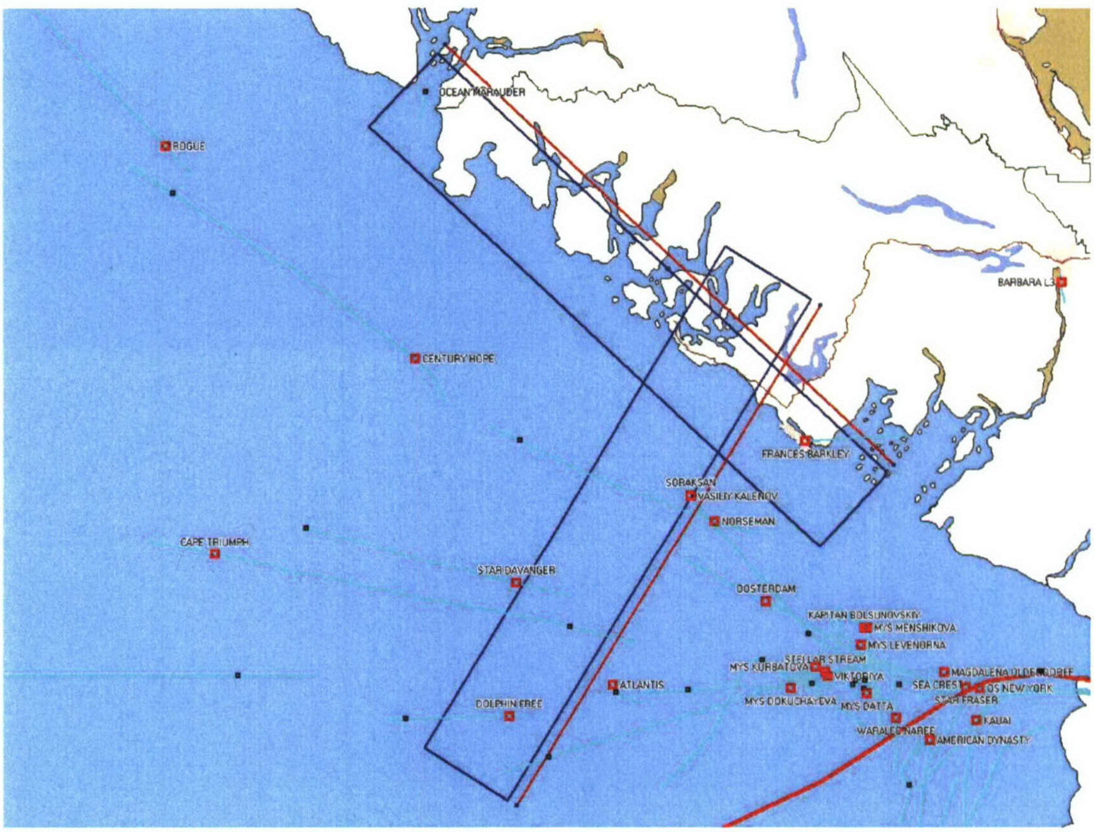

Figure K.21. *Map illustrating the CV-580 SAR acquisition scenario for 24 Sept. 2004: the nominal SAR coverage swaths (dark blue boxes) are shown along with the aircraft nadir (red lines); MCTS vessel tracks (cyan) include the vessel name and position (red box) at the start of the first flight line and the position (black square) at the end of the final flight line.*

Table K.10. *24 Sept. 2004, Line 2 Pass 8.*

On time (UTC)	22:19:33			
Off time (UTC)	22:33:56			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Frances Barkley	22:23:00	48.933	-125.533	
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 1	21:29:22	49.077	-125.933	K.36
Weigh West 1	21:37:51	49.102	-125.977	K.39
Starlight	21:45:22	49.173	-126.093	K.40
Private Boat 2	21:54:26	49.253	-126.296	K.41
Private Boat 3	22:01:39	49.242	-126.064	K.42
Private Boat 4	22:03:56	49.226	-125.991	K.43
Private Boat 5	22:04:02	49.226	-125.977	K.44
Private Boat 6	22:05:02	49.328	-125.978	K.45
Private Boat 8	22:05:40	49.229	-125.981	K.46
Private Boat 9	22:05:42	49.229	-125.975	K.47
Private Boat 10	22:05:56	49.226	-125.968	K.48
Fishing Boat 2	22:07:38	49.190	-125.923	K.49
Barge 1	22:08:19	49.190	-125.929	K.50
Tug Boat	22:08:29	49.192	-125.928	K.51
Dock Area	22:09:15	49.179	-125.906	K.52
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54
Buoy L2P8	22:03:10	49.223	-126.019	K.55

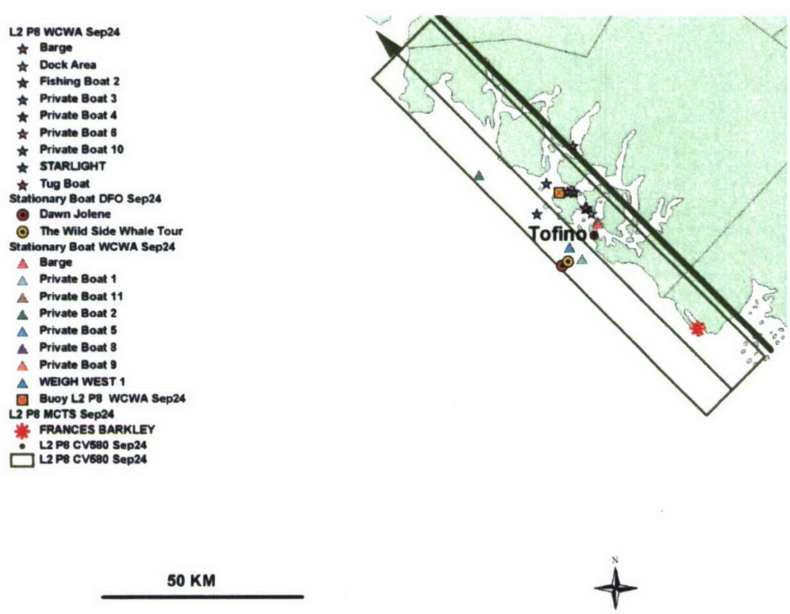

Figure K.22. *24 Sept. 2004, Line 2 Pass 8.*

Table K.11. *24 Sept. 2004, Line 1 Pass 2.*

On time (UTC)	19:59:34			
Off time (UTC)	20:16:40			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	20:04:00	48.833	-125.855	
Dolphin Free	20:15:00	48.426	-126.397	
Vasiliy Kalenov	20:04:00	48.832	-125.853	
DFO Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Northern Princess #1	19:59:24	48.32	-126.40	K.57
Dolphin Free	20:01:24	48.40	-126.40	K.58
Royal Spirit	20:08:16	48.58	-126.21	K.59
Bastion	20:10:03	48.58	-126.08	K.60
Shylo	20:11:40	48.57	-126.06	K.61
Kokanee	20:15:13	48.70	-126.05	K.62
Soraksan+Kalenov	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan+Kalenov	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Private Boat 1	21:29:22	49.077	-125.933	K.36
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54

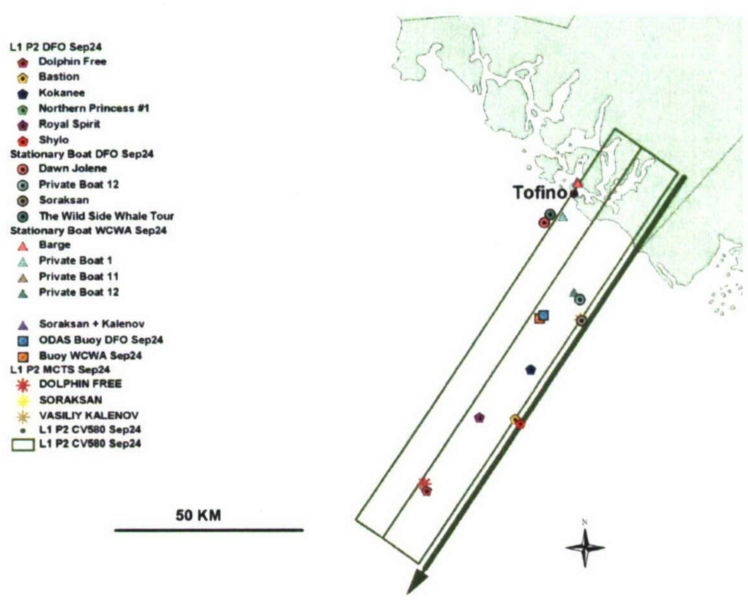

Figure K.23. *24 Sept. 2004, Line 1 Pass 2.*

Table K.12. 24 Sept. 2004, Line 1 Pass 3.

On time (UTC)	20:23:38			
Off time (UTC)	20:34:17			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	20:25:00	48.833	-125.855	
Norseman	20:25:00	48.808	-125.883	
Vasiliy Kalenov	20:25:00	48.832	-125.853	
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Soraksan+Kalenov	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Ocean Rover	20:26:49	48.88	-126.08	K.66
Spring Bandit	20:29:13	48.92	-126.05	K.67
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
Dawn Venture (tower)	20:24:20	48.85	-126.08	K.70
Rainbow Chaser II (towed)	20:25:47	48.85	-126.08	K.71
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan+Kalenov	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Private Boat 1	21:29:22	49.077	-125.933	K.36
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54

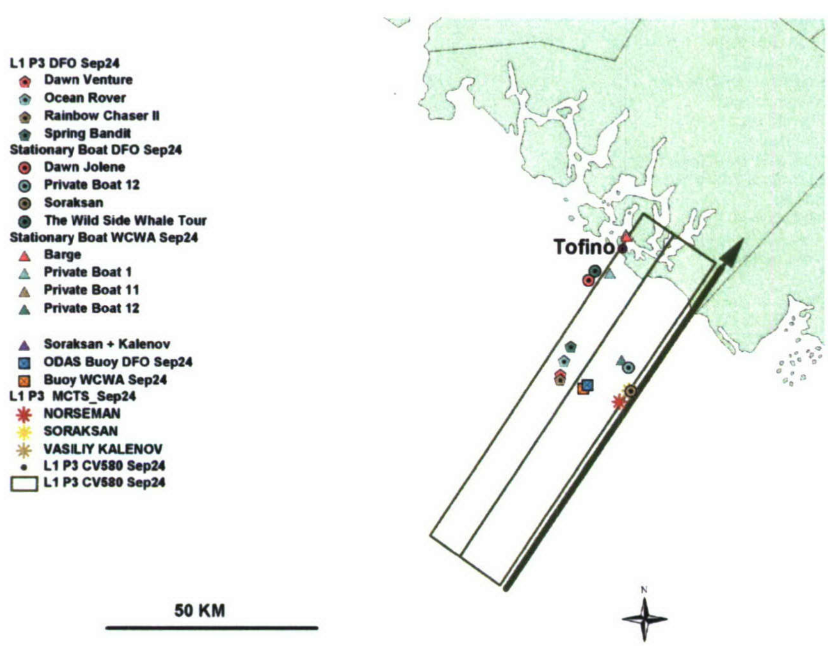

Figure K.24. *24 Sept. 2004, Line 1 Pass 3.*

Table K.13. *24 Sept. 2004, Line 1 Pass 4.*

On time (UTC)	20:45:51			
Off time (UTC)	21:00:28			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	20:55:00	48.833	-125.855	
Norseman	20:55:00	48.833	-125.985	
Dolphin Free	21:01:00	48.424	-126.484	
Vasiliy Kalenov	20:55:00	48.832	-125.853	
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Soraksan	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan+Kalenov	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Private Boat 1	21:29:22	49.077	-125.933	K.36
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54
Kokanee	21:04:10	48.627	-126.010	K.55

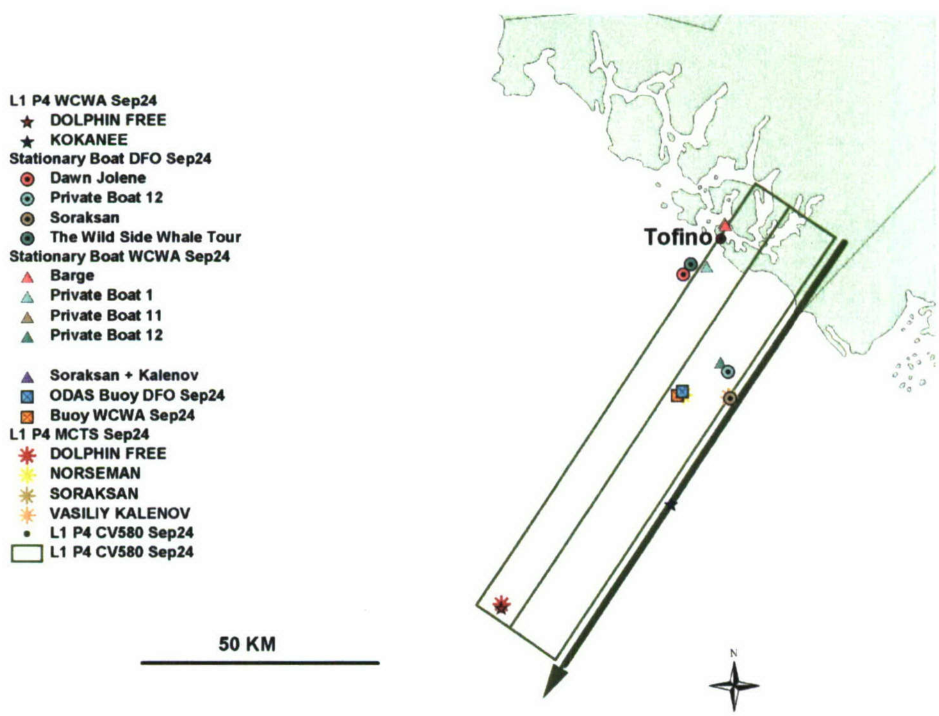

Figure K.25. *24 Sept. 2004, Line 1 Pass 4.*

Table K.14. *24 Sept. 2004, Line 1 Pass 5.*

On time (UTC)	21:09:26			
Off time (UTC)	21:18:55			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Soraksan	21:01:00	48.833	-125.855	
Norseman	21:14:00	48.847	-125.045	
Vasiliy Kalenov	21:12:00	48.793	-125.808	
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Soraksan	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Dawn Venture (tower)	21:12:22	48.863	-125.972	K.32
Rainbow Chaser II (towed)	21:12:31	48.863	-125.972	K.33
Ocean Rover	21:15:16	48.901	-125.919	K.34
Spring Bandit	21:17:05	48.924	-125.905	K.35
Private Boat 1	21:29:22	49.077	-125.933	K.36
Dagger Point	21:29:48	49.081	-125.939	K.37
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54

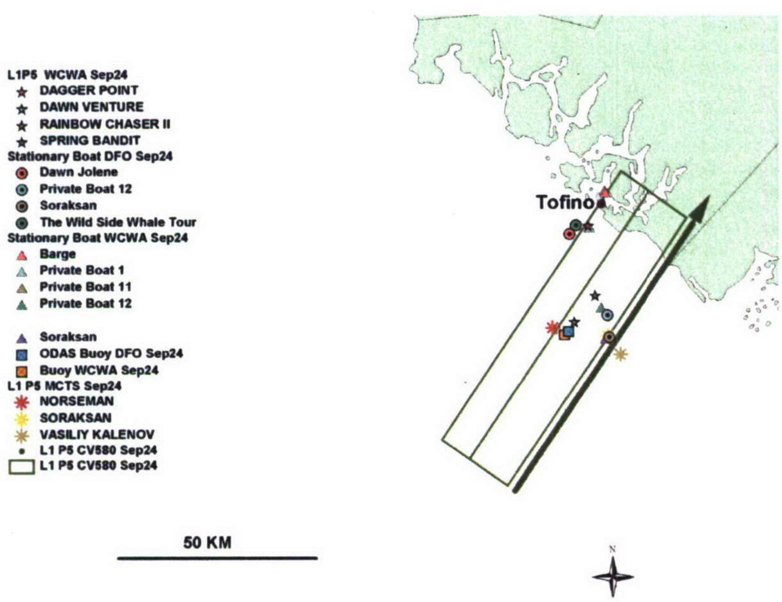

Figure K.26. *24 Sept. 2004, Line 1 Pass 5.*

Table K.15. 24 Sept. 2004, Line 1 Pass 6.

On time (UTC)	21:30:18			
Off time (UTC)	21:43:54			
MCTS NAME	**MCTS Time UTC**	**MCTS Lat**	**MCTS Long**	
Norseman	21:36:00	48.87	-126.133	
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Soraksan	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Spring Bandit	21:17:05	48.924	-125.905	K.35
Private Boat 1	21:29:22	49.077	-125.933	K.36
Dagger Point	21:29:48	49.081	-125.939	K.37
Dawn Jolene	21:33:23	49.054	-125.972	K.38
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54

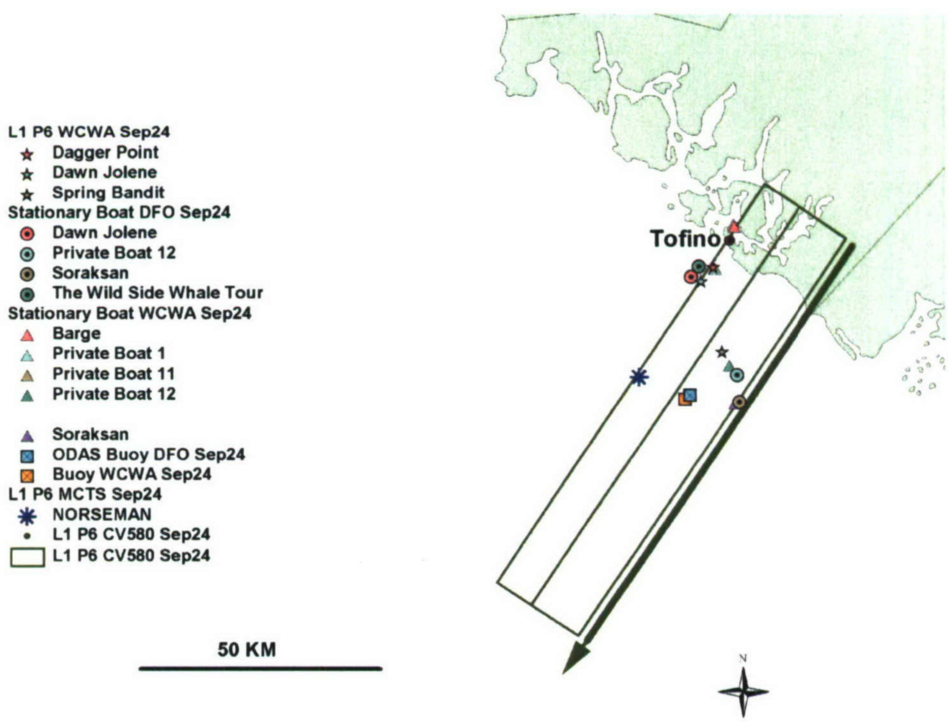

Figure K.27. *24 Sept. 2004, Line 1 Pass 6.*

Table K.16. 24 Sept. 2004, Line 1 Pass 7.

On time (UTC)	21:53:40			
Off time (UTC)	22:02:50			
DFO Photo Name	**DFO Time UTC**	**DFO Lat**	**DFO Long**	**Figure**
Soraksan	20:19:10	48.82	-125.85	K.63
Private Boat 12	20:20:28	48.87	-125.86	K.64
ODAS Buoy	20:22:52	48.83	-126.00	K.65
Dawn Jolene	20:36:10	49.05	-126.01	K.68
The Wild Side Whale Tour	20:36:55	49.07	-125.98	K.69
WCWA Name	**WCWA Time UTC**	**WCWA Lat**	**WCWA Long**	**Figure**
Private Boat 12	18:53:17	48.897	-125.883	K.29
Soraksan	18:57:12	48.827	-125.863	K.30
ODAS Buoy	21:10:03	48.832	-126.003	K.31
Private Boat 1	21:29:22	49.077	-125.933	K.36
Private Boat 11	22:09:53	49.161	-125.886	K.53
Barge 2	22:10:02	49.157	-125.883	K.54

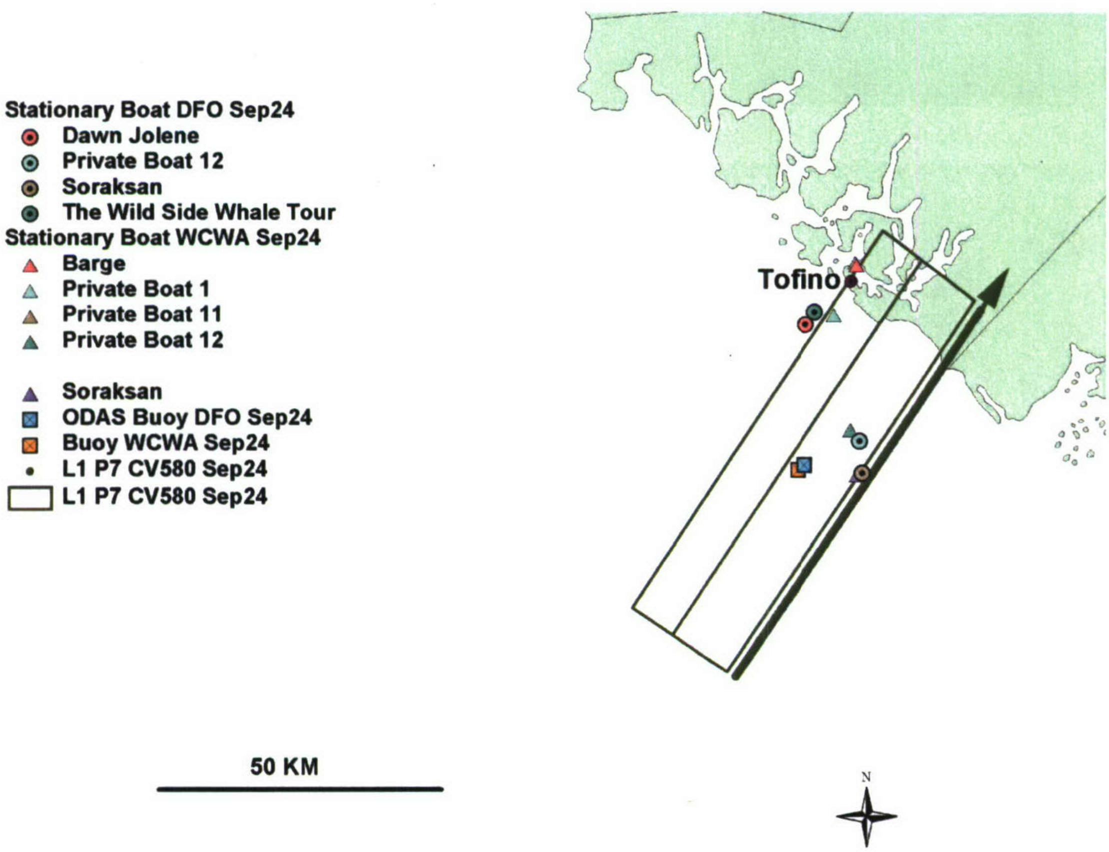

Figure K.28. 24 Sept. 2004, Line 1 Pass 7.

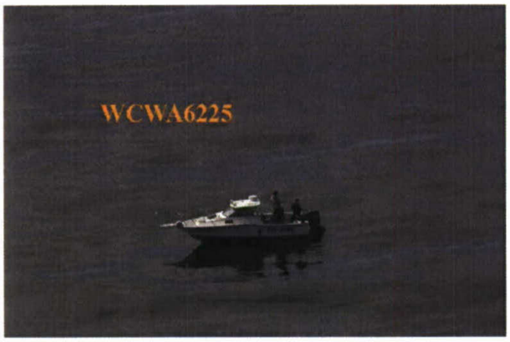

Figure K.29. *WCWA, Private Boat 12 (Fig. K.64).*

Figure K.30. *WCWA, Kalenov+Soraksan (Fig. K.63).*

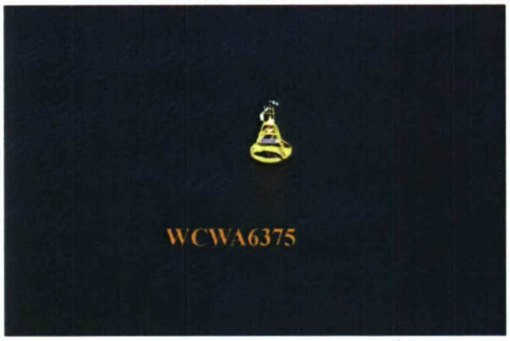

Figure K.31. *WCWA, ODAS Buoy (Fig. K.65).*

Figure K.32. *WCWA, Dawn Venture (Fig. K.70).*

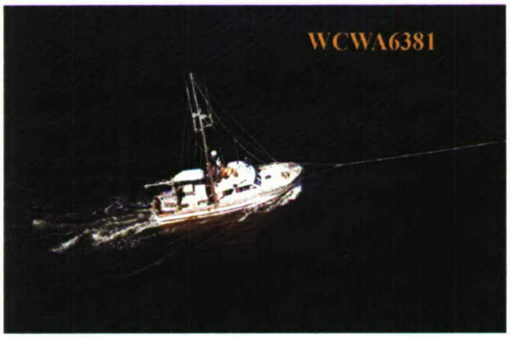

Figure K.33. *WCWA, Rainbow Chaser II (Fig. K.71).*

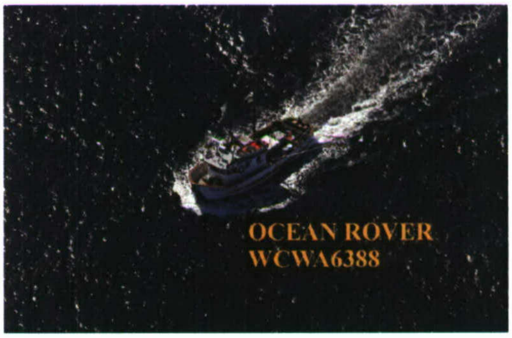

Figure K.34. *WCWA, Ocean Rover.*

Figure K.35. *WCWA, Spring Bandit (Fig. K.67).*

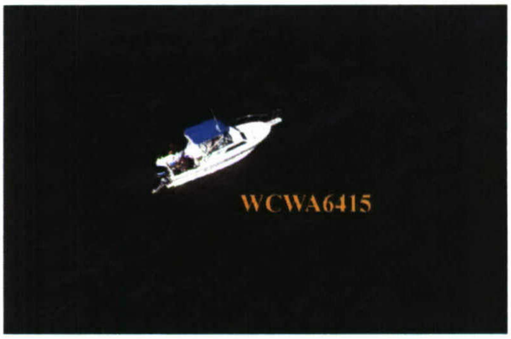

Figure K.36. *WCWA, Private Boat 1.*

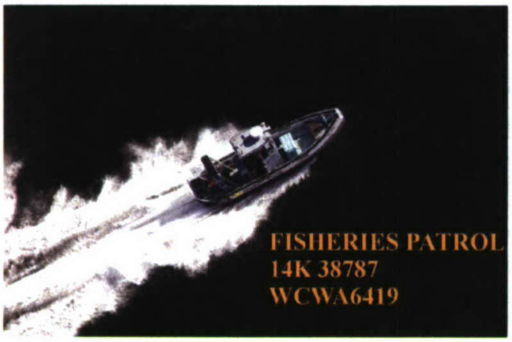

Figure K.37. *WCWA, Dagger Point.*

Figure K.38. *WCWA, Dawn Jolene (see Fig. K.68).*

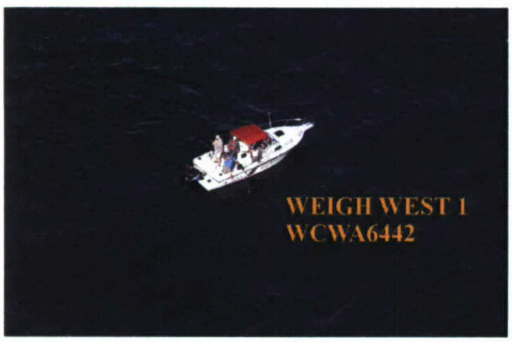

Figure K.39. *WCWA, Weigh West 1.*

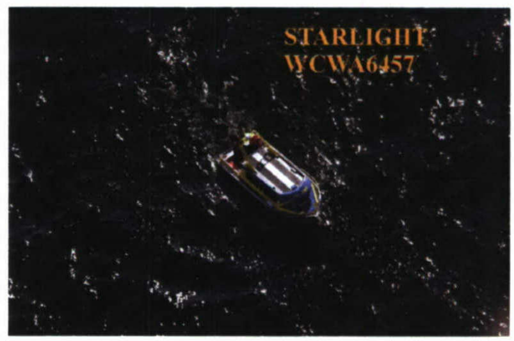

Figure K.40. *WCWA, Starlight, Tour Boat.*

Figure K.41. *WCWA, Private Boat 2.*

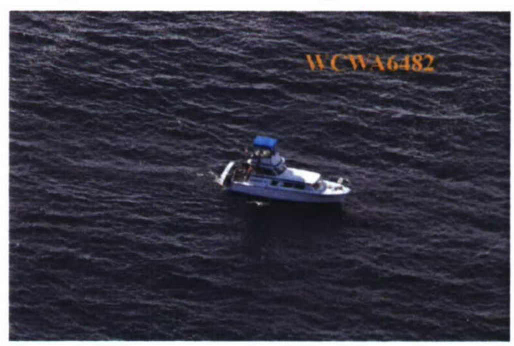

Figure K.42. *WCWA, Private Boat 3.*

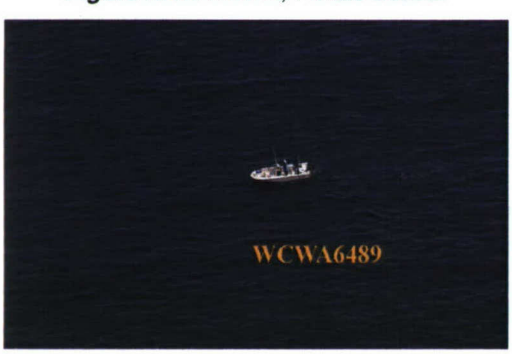

Figure K.43. *WCWA, Private Boat 4.*

Figure K.44. *WCWA, Private Boat 5.*

Figure K.45. *WCWA, Private Boat 6.*

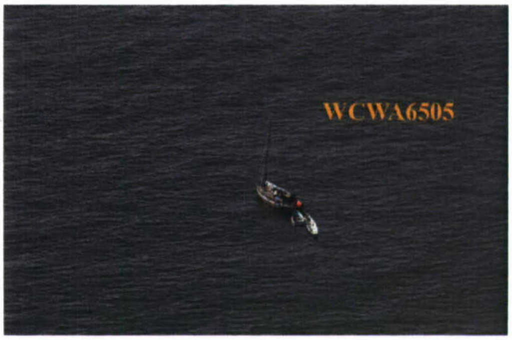

Figure K.46. *WCWA, Private Boat 8.*

Figure K.47. *WCWA, Private Boat 9.*

Figure K.48. *WCWA, Private Boat 10.*

Figure K.49. *WCWA, Fishing Boat 2.*

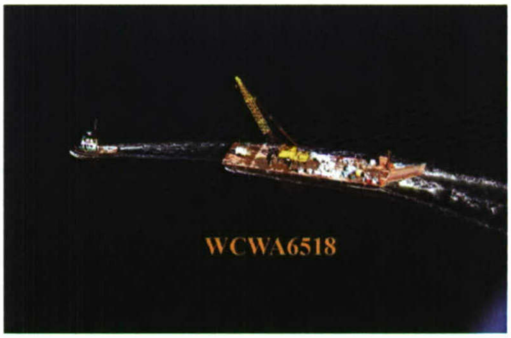

Figure K.50. *WCWA, Barge 1.*

Figure K.51. *WCWA, Tug Boat.*

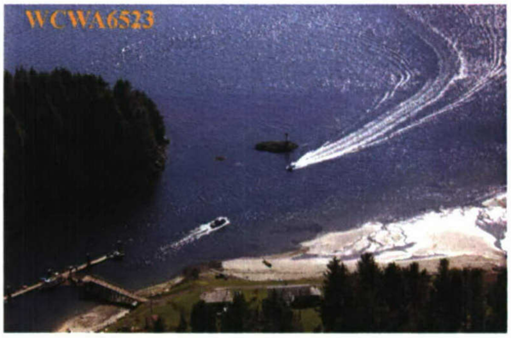

Figure K.52. *WCWA, Dock Area.*

Figure K.53. *WCWA, Private Boat 11.*

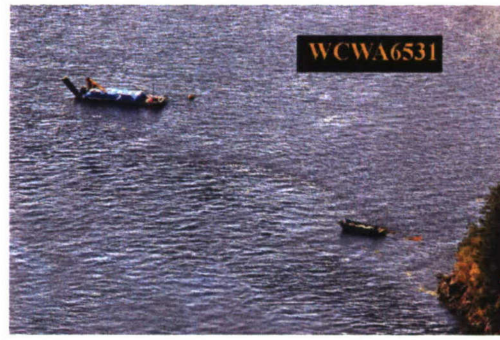

Figure K.54. *WCWA, Barges 2.*

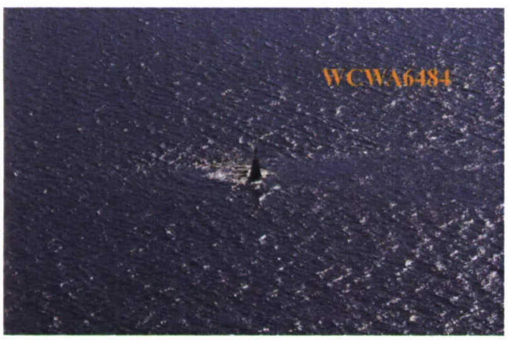

Figure K.55. *WCWA, Marker Buoy, L2P8.*

Figure K.56. *WCWA, Kokanee (Fig. K.62).*

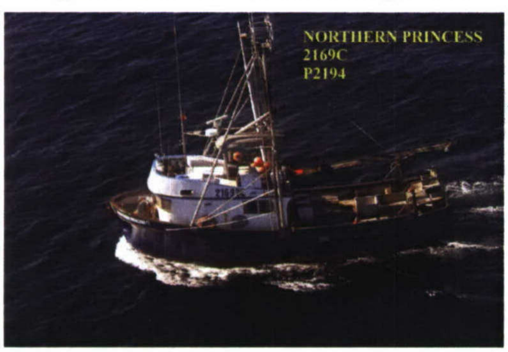

Figure K.57. *DFO, Northern Princess.*

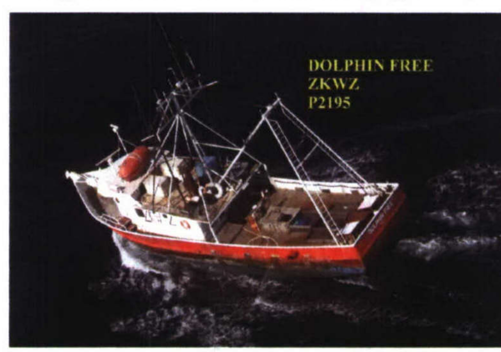

Figure K.58. *DFO, Dolphin Free.*

Figure K.59. *DFO, Royal Spirit.*

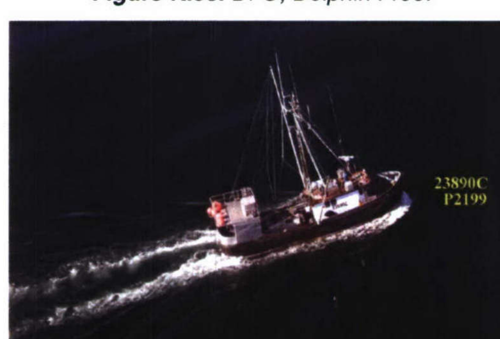

Figure K.60. *DFO, Bastion.*

Figure K.61. *DFO, Shylo.*

Figure K.62. *DFO, Kokanee (Fig. K.56).*

Figure K.63. *DFO, Kalenov+Soraksan (Fig. K.30).*

Figure K.64. *DFO, Private Boat 12 (Fig. K.29).*

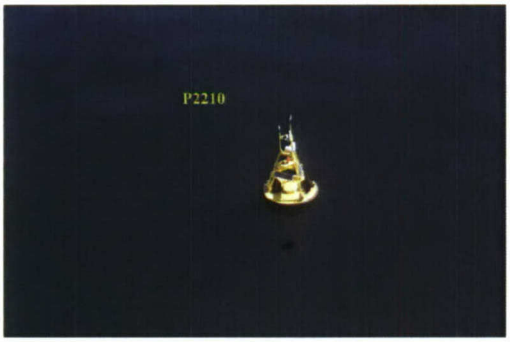

Figure K.65. *DFO, ODAS Buoy (Fig. K.31).*

Figure K.66. *DFO, Ocean Rover.*

Figure K.67. *DFO, Spring Bandit (Fig. K.35).*

Figure K.68. *DFO, Dawn Jolene (Fig. K.38).*

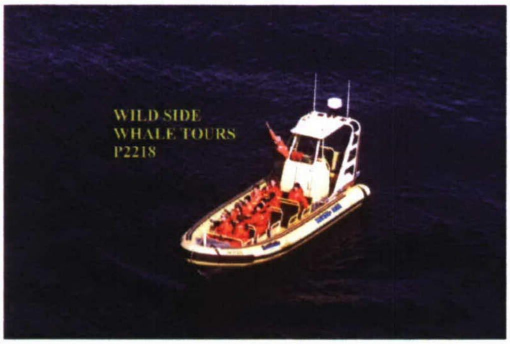

Figure K.69. *DFO, The Wild Side Whale Tours.*

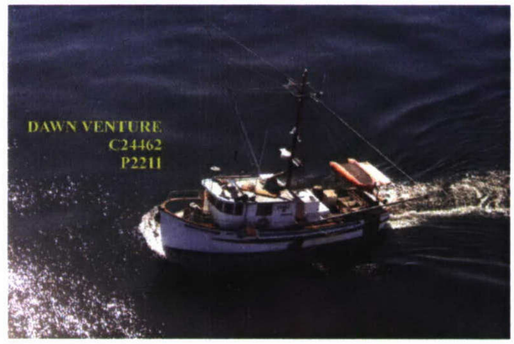

Figure K.70. *DFO, Dawn Venture (Fig. K.32).*

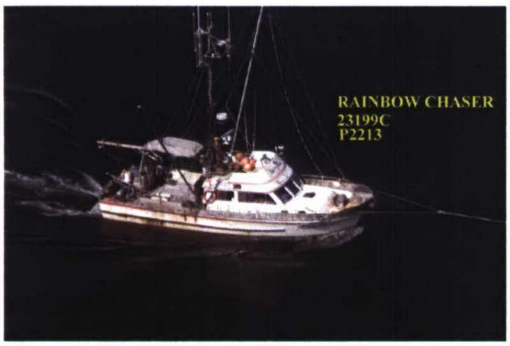

Figure K.71. *DFO, Rainbow Chaser II (Fig. K.33)*

Acronyms

$^\circ$T	degrees from True North
1 CAD	First Canadian Air Division
A/C	Aircraft
ADC	analogue-to-digital converter
AGL	altitude Above Ground Level
AIS	Automatic Identification System
AO	Acquisition Order
ARC	active radar calibrator
BC	British Columbia
Cal Site	calibration site
Capt	Captain
CBC	Canadian Broadcasting Company
CCG	Canadian Coast Guard
CCGC	Canadian Coast Guard Cutter
CCRS	Canada Centre for Remote Sensing
Cdr	Commander
CF	Canadian Forces
CFB	Canadian Forces Base
CFMETR	Canadian Forces Maritime Experimental and Test Ranges
COASP	Configurable Airborne SAR Processor
CoCoNaut	Collaborative Coastal and Nautical
CR	corner reflector
CSA	Canadian Space Agency
CSI	Commercial Satellite Imagery
CSRS	Canadian Spatial Reference System
CV-580	Convair 580
CYAZ	Tofino Airport
CYCD	Nanaimo Airport
CYQQ	Comox Airport
CYVR	Vancouver Airport
D Space D	Director Space Development
DFO	Department of Fisheries and Oceans
dGPS	differential GPS
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DTSES	Director Telecommunication and Spectrum Engineering and Support
E	east
EC	Environment Canada
EDT	Eastern Daylight Time
EM	electro-magnetic
EOADP	Earth Observation Application Development Program
ERU	Exciter/Receiver Unit

EST	Eastern Standard Time
ETD	Estimated Time of Departure
FM	Frequency Modulation
GIS	Geographic Information System
GMTI	Ground MTI
GPS	Global Positioning System
Grp	Group
GSD	Geodetic Survey Division
GSM	Global System for Mobile Communications
H/C	Helicopter
HAE	Height Above Ellipsoid (altitude)
HF	High Frequency
HH	horizontal transmit, horizontal receive
HV	horizontal transmit, vertical receive
ID	Identification
JD	Julian Day
L	left
LOS	line-of-sight
MAC (P)	Maritime Air Command (Pacific)
Maj	Major
MarCoPola	Maritime Cooperative Polarimetric
MCTS	Marine Communications and Traffic Service
MMTI	Maritime MTI
MPA	Maritime Patrol Aircraft
MSL	altitude above Mean Sea Level
MTI	Moving Target Indicator
N	north
N/R	Not Available
N/R	Not Recorded
NE	northeast
NOTAM	Notice to Airmen
NRCan	Natural Resources Canada
NW	northwest
ODAS	Oceanographic Data Acquisition System
Ops	Operations
PAL	Provincial Airlines
PDT	Pacific Daylight Time
PLIX	Pacific Littoral Experiment
PolSAR	polarimetric SAR
PST	Pacific Standard Time
R	right
R_x	receive
R/W	Runway
R&D	research and development
RAST	Radar Application and Space Technology

RCS	Radar Cross Section
RDE	Radar Data Exploitation
RF	radio frequency
RGD	Range Gate Delay
RMP	Recognized Maritime Picture
RS	Radar Systems
RSC	Romeo Sierra Charlie — CV-580 callsign
RSI	RADARSAT International
S	south
S/B	Sideband
SAR	Synthetic Aperture Radar
SBR	Space Based Radar
SE	southeast
Sgt	Sergeant
Sqn	Squadron
SSW	south-southwest
SUV	Sport Utility Vehicle
SW	southwest
T_x	transmit
T/W	Taxiway
TCR	target to clutter
U/SB	Upper Sideband
UHF	Ultra High Frequency
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VH	vertical transmit, horizontal receive
VHF	Very High Frequency
VPI	Vantage Point International
VV	vertical transmit, vertical receive
W	west
WCWA	West Coast Wild Adventures

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(U) This memorandum addresses DRDC Ottawa design, experimentation, and data collection components in the CoCoNaut airborne Synthetic Aperture Radar (SAR) trial conducted off Vancouver Island, BC, 15 September - 4 October, 2004, in conjunction with a Canadian Space Agency (CSA) deployment. Several controlled ships (commercial, military and Coast Guard) and land-based vehicles were instrumented as targets for polarimetric SAR (PolSAR) and Moving Target Indication (MTI) data acquisitions.

(U) C-band SAR imagery was collected using the sensor on Environment Canada's CV-580 platform, with a radar calibration site was established at the Tofino Airport (CYAZ). Ground-truthing for targets of opportunity was highly desired and supporting efforts made to identify them through contact tracking and photography, employing CP-140 maritime partrol aircaft, aerial creel survey flights, Marine Communications and Traffic Service, contracted aerial photography flights, and the Recognized Maritime Picture (RMP).

(U) Twenty lines of PolSAR data were collected, each covering a wide swath containing maritime targets of opportunity and all include the calibration site at CYAZ. Eight also contain a controlled CCG vessel exhibiting various speeds, incidence angles and aspect angles. Thirty-two lines of MTI data were collected. Sixteen contain controlled maritime targets, seven contain controlled land-based vehicles, four (one maritime, three land) contain only targets of opportunity, and five are calibration lines. Three further flights of PolSAR imagery were collected by CSA, each including a calibration pass over CYAZ. A representative analysis of a maritime target in PolSAR imagery is provided.

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Polarimetry, Polarimetric Synthetic Aperture Radar (PolSAR), Polarimetric Signatures, Maritime Target Detection, Maritime Target Identification, Moving Target Indicator.

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